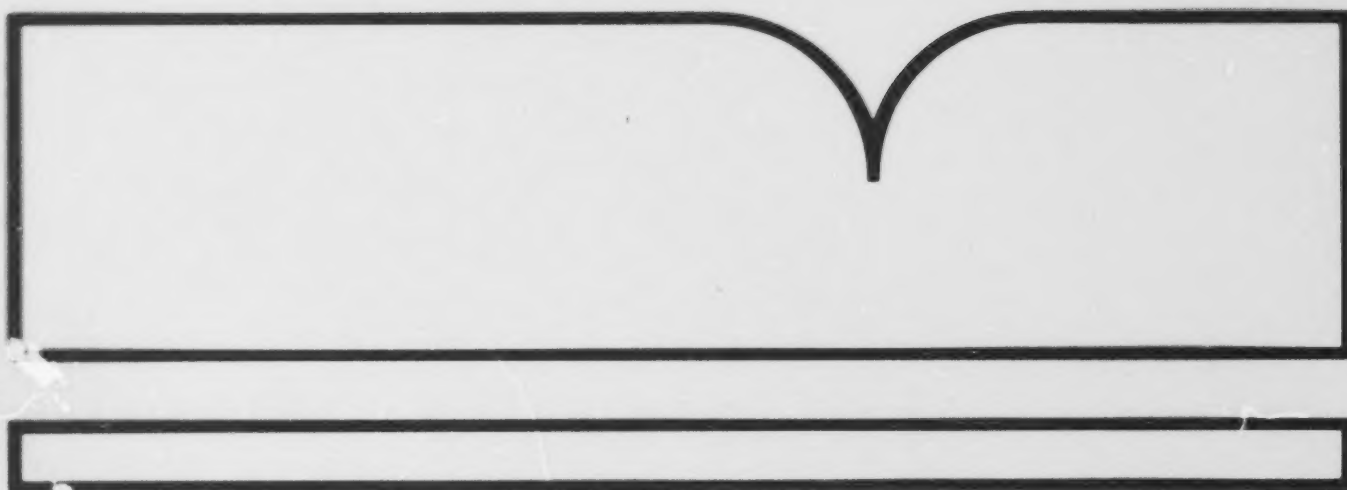


Criteria for Municipal Solid Waste Landfills
(40 CFR Part 258). Subtitle D of Resource
Conservation and Recovery Act (RCRA). Regulatory
Impact Analysis (RIA) of Proposed Revisions to
Subtitle D Criteria for Municipal Solid
Waste Landfills

(U.S.) Environmental Protection Agency
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In August 1988, the U.S. Environmental Protection Agency proposed Solid Waste Disposal Facilities Criteria (40 CFR Part 258) for municipal solid waste landfills. This background document presents the Regulatory Impact Analysis (RIA) that was prepared to evaluate the Agency's proposed revisions to the Subtitle D Criteria for municipal solid waste landfills. The RIA evaluates the regulatory proposal relative to three alternatives in terms of costs, economic impacts, impacts on small entities, risk, and resource damage.				
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BACKGROUND DOCUMENT**

**REGULATORY IMPACT ANALYSIS (RIA)
OF PROPOSED REVISIONS TO
SUBTITLE D CRITERIA FOR
MUNICIPAL SOLID WASTE LANDFILLS**

**"CRITERIA FOR MUNICIPAL SOLID WASTE LANDFILLS"
(40 CFR PART 258)**

**SUBTITLE D OF RESOURCE CONSERVATION AND
RECOVERY ACT (RCRA)**

**U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF SOLID WASTE**

**REPRODUCED BY
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SPRINGFIELD, VA 22101**

AUGUST 1988

Draft Regulatory Impact Analysis of Proposed Revisions to Subtitle D Criteria for Municipal Solid Waste Landfills

Prepared for

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U.S. Environmental Protection Agency

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August 5, 1988

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CONTENTS

	<u>Page</u>
ACKNOWLEDGMENTS	1
NOTE TO READERS	2
OVERVIEW OF THE SUBTITLE D RIA	4
EXECUTIVE SUMMARY	9
Proposed Rule	10
Regulatory Alternatives	12
Analytical Methodology	14
Results	17
Cost-Effectiveness	28
Limitations	31
I. INTRODUCTION	I-1
The Federal Role in Solid Waste Disposal	I-1
The Nature of the Problem	I-1
Required Analyses	I-2
Outline of the Report	I-3
II. BACKGROUND	II-1
Current Regulatory Requirements	II-1
Characteristics of Affected Landfills	II-6

CONTENTS
(continued)

	<u>Page</u>
III. REGULATORY OPTIONS	III-1
Proposal	III-1
Alternative 1	III-4
Alternative 2	III-5
Alternative 3	III-6
IV. METHODOLOGY	IV-1
Cost Analysis	IV-1
Economic Impact Analysis	IV-27
Risk and Resource Damage Analysis	IV-51
V. RESULTS	V-1
Costs	V-1
Economic Impacts	V-40
Regulatory Flexibility Analysis	V-61
Risk and Resource Damage	V-67
VI. COST-EFFECTIVENESS	VI-1
Costs of Risk Reduction	VI-2
Costs for Resource Damage Reduction	VI-4
Summary	VI-6

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NOTE TO READERS

This note to readers addresses several current provisions of the proposed rule that do not exactly reflect what was analyzed in the RIA (e.g., performance standard for existing units, post-closure care, and ground-water monitoring parameters). As a consequence, the results presented in the RIA may understate the fraction of existing municipal solid waste landfills (MSWLFs) requiring more stringent covers (and the resulting costs of these covers); overstate costs for post-closure care; and understate the sampling costs for ground-water monitoring. Nonetheless, we believe the basic conclusions of the draft RIA are accurate estimators of the effects of the proposed rule. These new provisions (described below) will be completely analyzed when the draft RIA is revised for promulgation.

PERFORMANCE STANDARD FOR EXISTING UNITS

The Proposal specifies that existing units should be designed with a final cover that will prevent infiltration of water into the cover and into the waste following landfill closure. Rigorous modeling of this performance standard would require an extensive additional modeling effort that was not possible because of time and budget constraints. This additional effort would involve evaluating the factors affecting infiltration (cover design, permeability, run-off, precipitation, and evapotranspiration). Designs that would prevent infiltration would then be assigned to landfills depending on their environmental setting.

We did, however, use modeled risk at a set of new landfills to assign vegetative or synthetic covers to existing MSWLFs. We determined the environmental settings in which risk at the compliance point would exceed the Proposal performance standard (design goal), and assigned low permeability, synthetic covers to existing landfills in those same settings. Because our assignment was based on risk and not infiltration, we may have underestimated the fraction of existing landfills requiring synthetic covers.

GROUND-WATER MONITORING PARAMETERS

The Proposal calls for a two-phased monitoring program as described in Chapter IV of the RIA. While we simulated a three-phased program that is generally consistent with the Proposal, the total cost for sampling is likely to be higher under the Proposal.

The parameters we included in the first and second phases of monitoring would cost approximately \$60 and \$520 (respectively) to sample and analyze. The current Proposal calls for a first phase that essentially combines these two phases plus additional constituents at a cost per sample of \$644.

The list of constituents for phase three that was modeled in the RIA is the same as the constituent list for phase two in the Proposal. Phase two costs are less certain under the Proposal because they include a one-time scan of constituents with subsequent regular monitoring of those constituents identified in the scan. As a result we have overstated sampling costs in this phase to the extent that subsequent monitoring is for only a subset of parameters from the initial full scan.

We believe the net effect is that the total costs of sampling in the RIA understate the actual sampling costs required by the proposed rule.

POST-CLOSURE CARE PERIOD

The Proposal calls for a two-phased post-closure care period. The first phase lasts for 30 years and includes cover maintenance and monitoring. The duration of the second phase is to be set by the states and requires, at a minimum, ground-water and gas monitoring. The Risk Model is generally consistent with these conditions, although it sets the second phase of post-closure care at 50 years. The Cost Model assumes that post-closure care continues indefinitely. In fact, under the Proposal some states may elect to extend post-closure monitoring for this duration, but we also included costs for additional requirements that the states may not impose (maintenance and inspection of the facility beyond the initial 30 years). The post-closure costs are overestimated somewhat as a result.

OVERVIEW OF THE SUBTITLE D RIA

The following is an overview of the findings and limitations of the draft Subtitle D Regulatory Impact Analysis. The proposed rule establishes general facility standards, ground-water monitoring, two-phased post-closure care, corrective action, and performance standards for the design of municipal solid waste landfills (MSWLFs).

Summarized below are the highlights of the regulatory impact analysis for the proposed rule. These results are supported by months of intense data collection and analysis and represent EPA's best efforts to quantify the costs and benefits of the Proposal. Nevertheless, as in any analysis, the results are necessarily based on incomplete data and on simplifying assumptions. To accurately interpret the results, we have identified below the principal caveats to the analysis.

- The national cost estimates represent upperbound estimates; they do not consider regionalization, resource recovery, increases in recycling, or the siting of new landfills in "good" locations. For simplicity, we assume that all existing MSWLFs will eventually be replaced with new MSWLFs that meet the proposed requirements.
- The risk estimates consider only ground-water risks over the next 300 years at drinking water wells within one mile of a facility, assuming current population distributions; they do not address the risk from releases to surface water, nor do they address effects on ecosystems.
- The results presented in the RIA assume that all states will impose a 10^{-5} design goal on MSWLFs from the allowable protective range of 10^{-4} to 10^{-7} . Actual costs, benefits, and economic impact results will differ according to the actual design goal established by each state within this risk range.

FINDINGS

The proposed rule reduces risk at new MSWLFs and saves \$1.3 billion (present value) in ground-water resource damages for a set of 6,034 new landfills, assuming compliance with the design goal at the waste management unit boundary (10-meter point

of compliance or POC). Assuming a POC at 150 meters from the waste boundary (150-meter POC), the Proposal saves \$0.98 billion in resource damage.

The present value of costs for existing landfills and for new replacement landfills that comply with the Proposal in perpetuity are \$29,300 million using the 10-meter POC and \$23,000 million using the 150-meter POC.

1. Benefits

The Proposal imposes risk-based performance criteria that confer risk and resource damage benefits (which are mutually exclusive measures of benefits in this analysis) from baseline conditions. The Proposal:

- Eliminates roughly 17 cancer cases over 300 years using either POC (0.0560 cases per year at the 10-meter POC and 0.0543 cases per year at the 150-meter POC)
- Reduces risk to the point that only 13 percent (14 percent under the 150-meter POC) of the landfills pose an actual most exposed individual (MEI) risk greater than 10^{-6} and virtually none (0.1 percent) poses an MEI risk greater than 10^{-5} for either POC
- Saves over \$1.3 billion (present value) in resource damage under the 10-meter POC and \$0.98 billion under the 150-meter POC

Without this regulation:

- The risks to the most exposed individual from uncontrolled MSWLFs would range from zero to 10^{-4} , with 66 percent of the MSWLFs posing hypothetical risk at their facility boundary from 10^{-4} to 10^{-6} and 17 percent posing actual risks greater than 10^{-6}
- Nearly three-fourths of the MSWLFs would trigger resource damages

Although we believe that these estimates are good approximations of the potential benefits of the Proposal, several important caveats, noted below, must be understood for a proper interpretation of the results.

Only Effects from Contaminated Ground Water Are Considered

The RIA quantifies benefits from reducing ground-water contamination only. These include reducing human health risks caused by drinking contaminated ground water, and reducing the resource damage effects from domestic use of contaminated drinking water. We also expect that there will be risks (to human health and the environment) from subsurface gas and from releases to surface water and that controlling them will result in subsequent regulatory benefits.

Effects of Changing Population Demographics Are Not Considered

Future population growth near MSWLFs would increase the human health risk from uncontrolled MSWLFs and increase the benefits of the Proposal. However, population growth would also increase the volume of solid waste and the total cost of disposal. Moreover, if fewer landfills are sited because of regionalization, the effects of population growth may be offset. (Although the risk analysis does not account for future population growth, the resource damage estimates do incorporate the probabilistic, future use of the ground water as a drinking water source).

Benefits Beyond 300 Years Are Ignored

The RIA quantifies risk reduction only over 300 years; we would expect greater benefits over an extended period. Extending the modeling period beyond 300 years, however, would not affect the Proposal's cost-effectiveness.

2. Costs and Impacts

The total annualized cost of the Proposal is \$880 million for the 10-meter POC and \$691 million for the 150-meter POC. The median annualized incremental cost per ton for the 10-meter POC is \$11.01 (or \$43,600 per landfill) over the current estimated average cost of \$35 per ton, while for the 150-meter POC the median is \$9.54 per ton (or \$38,800 per MSWLF); the cost per household varies widely but averages \$11 per year for the 10-meter POC and \$8 per year for the 150-meter POC.

These costs do not result in a high percentage of significant economic impacts to communities or individual households. For the proposed rule:

- Using the 10-meter POC, 84 percent of all communities (representing 93 percent of the total population) will face compliance costs of less than 1 percent of their total current expenditures; under the 150-meter POC, 89 percent of all communities (representing 96 percent of the population) will face similar economic impacts.
- Nearly 99 percent of all communities will face incremental costs per household of less than \$100 per year.
- No households will face compliance costs greater than 1 percent of their median household income under the 10-meter POC; under the alternative POC, less than 0.5 percent exceed this threshold.

The cost and impact estimates do not appear to have significant community or individual household effects. Although the aggregate cost appears high, it may actually be less than estimated for the following reasons.

Regionalization May Lower the Costs

Communities owning small MSWLFs can achieve substantial economies of scale by combining with other similar communities to cooperate in a larger regional landfill. This would reduce, but not eliminate, regulatory costs. For example, a small MSWLF (10 tons per day) currently operates at about \$55 per ton (full cost allocation), while a large MSWLF (receiving 1,500 tons per day) operates at \$6 per ton. Since smaller landfills and the communities they service will face a greater relative cost burden than larger ones, owners of small MSWLFs will likely find it attractive to regionalize to larger landfills.

Some States May Already Be Meeting Proposed Requirements

The total estimated compliance costs may be overstated because some states have aggressive solid waste programs that may be similar to the Proposal. Although we adjusted the costs for MSWLFs in those states that already have ground-water monitoring wells or containment system requirements (e.g., liners, leachate collection systems) as stringent as the proposed rule, we did not incorporate other current state requirements.

Shifts to Resource Recovery
Will Lower Proposal Costs

Municipal waste combustion will potentially reduce compliance costs by diverting as much as 18 percent of the solid waste generated over the next 15 years from land disposal. This shift will likely be large in the eastern seaboard states, where landfill capacity is limited and environmental factors will increase per-unit compliance costs. To the extent that this shift occurs, the actual cost of the Proposal will be lower.

3. Cost-Effectiveness

Although the Proposal will reduce risk and save approximately \$1 billion (present value) in resource damage, it does so at a present value cost per case avoided of \$708 million under the 10-meter POC or \$548 million under the 150-meter POC, and a present value of \$0.11 of resource damage avoided per dollar of compliance cost (for both POCs).

The cost per case avoided is strongly influenced by the current population and drinking water well distribution: 54 percent of the MSWLFs are located more than one mile from the nearest drinking water well. If populations increase near MSWLFs and more people become exposed, the cost-effectiveness would improve. For example, if the 3,258 MSWLFs without nearby wells had drinking water well distributions similar to those MSWLFs with nearby wells, the cost per case avoided would decrease to \$331 million under the 10-meter POC and \$264 million under the 150-meter POC. The cost-effectiveness estimates are thus very sensitive to the current population and well distributions.

SUMMARY

Many assumptions, like those discussed above, enter into the risk and cost analysis. Thus, strong reliance on the absolute risk or cost-effectiveness estimates without full realization of the limitations of the analysis should be avoided. Comparisons of the risk estimates across regulatory options are more reliable and valid than absolute estimates for a single option.

EXECUTIVE SUMMARY

This draft Regulatory Impact Analysis (RIA) was prepared to evaluate the U.S. Environmental Protection Agency's (EPA's) proposed revisions to Subtitle D criteria for municipal solid waste landfills. These regulations are a major rule according to Executive Order 12291 (aggregate compliance costs greater than \$100 million per year) and, therefore, an RIA is required as part of this rule-making. The analysis in this report evaluates the regulatory proposal relative to three alternatives in terms of costs, economic impacts, impacts on small entities, risk, and resource damage.

Preliminary estimates from EPA's Solid Waste (Municipal) Survey indicate that there are 6,034 active municipal solid waste landfills (MSWLFs) in the United States today. All of these facilities must comply with the current Subtitle D Criteria (40 CFR Part 257) promulgated by EPA in 1979. While EPA established these criteria, each state has the responsibility of ensuring that its MSWLFs meet these criteria as well as any other requirements that the state may have.

The characteristics of MSWLFs as reported in the EPA municipal landfill survey vary significantly across the country on a number of parameters: environmental setting, size, ownership, and remaining life. Environmental setting affects the potential for ground-water contamination. Landfill size is an important parameter because of the tremendous economies of scale in landfill operations (larger facilities can dispose of waste at a lower unit cost). The reported size of landfills covers a wide spectrum from very small local landfills receiving one ton of waste a day or less to large landfills that receive thousands of tons of waste each day. Most landfills are at the small end of the spectrum, with 51 percent of all landfills estimated to be receiving less than 17.5 tons per day (TPD) of waste and 81 percent receiving less than 125 TPD. In terms of total waste disposed, the large facilities dispose of the vast majority of all municipal solid waste (MSW) generated in the United States (landfills over 1,125 TPD handle 40 percent of all waste generated but account for only 3 percent of all MSWLFs).

The third parameter is ownership; it is important because landfill owners will bear the responsibility of complying with revised criteria. Most MSWLFs (81 percent) are owned by local governments, including counties, cities, towns, and villages. Approximately 15 percent of all landfills are privately owned. The remaining 4 percent of landfills are owned by the federal

government at national parks, military bases, and other federal installations and by state governments at parks, universities, and other locations. While landfill owners will bear the responsibility of compliance with these revised criteria, the ultimate cost of compliance will eventually fall on landfill users, through increased user fees, higher taxes, or a reallocation of funds within the local municipality's budget, resulting in reduced services elsewhere.

The fourth parameter is remaining life. This is an important characteristic because it establishes the remaining time that existing facilities have to recover the cost of this regulation from current operations. If this cannot be achieved, other funding sources will be required such as a surcharge on ongoing disposal operations or a transfer of tax revenues. It is also important because existing and new landfills will be regulated differently. The landfill survey results show that 55 percent of the MSWLFs currently in operation will close within ten years; another 25 percent will close in the following ten years. In other words, 80 percent of all municipal landfills in use today will be closed in 20 years and will have to be replaced with new landfill capacity or other disposal techniques. Of the remaining 20 percent of landfills that will operate beyond 20 years, 5 percent are projected to continue operation for 100 years or more.

PROPOSED RULE

The proposed regulatory approach establishes performance standards that landfills must meet. These standards differ for new and existing landfill units. In addition, the Proposal includes a set of general facility standards. While all landfills must meet the general standards, only those that do not meet the relevant performance standard must comply with additional requirements.

For new units the performance standard is linked to a health- and environmental-based ground-water risk level called the design goal. If the landfill will not meet the design goal once it has complied with the general facility standards, then additional controls are needed. The Proposal specifies only that the design goal must fall in the protective range of risk levels between 10^{-4} and 10^{-7} ; individual states are responsible for choosing the relevant design goal for units in their states. The Proposal also does not set specific designs that landfill owners must use to meet the design goal. Any controls approved by the state that will result in the landfill meeting the performance standard are acceptable.

The performance standard for existing units is less stringent and recognizes the technical and financial constraints on adding controls to existing landfills. The performance standard requires that the final cover prevent infiltration into the waste.

Although the Proposal does not specify a particular design goal (only a range) or particular MSWLF designs, we selected one design goal and several designs in order to model the costs, economic impacts, and effectiveness of the Proposal. We chose a design goal of 10^{-5} and then modeled three different design options and corrective action if the most protective design would not meet this design goal. If a different design goal were used in the modeling, the results of the cost and effectiveness analysis would change.

The design options are an unlined unit with a vegetative cover (the same design we used for a baseline) if the design goal is already met under baseline conditions; an unlined unit with a synthetic cover; a synthetic liner plus leachate collection system (LCS) and synthetic cover; and a synthetic liner with LCS and cover plus corrective action. We assumed that units would comply with the rule by installing the least expensive design that would meet the design goal. To assign designs, we compared the design goal with constituent concentrations that would result in a 300-year average most exposed individual risk to humans of 10^{-5} . Finally, we analyzed the Proposal at two points of compliance (POCs). As allowed by the Proposal, the design goal could be met at the unit boundary (modeled as a monitoring well 10 meters from the waste unit boundary) or at an alternative point of compliance defined by the state. This alternative POC can be up to 150 meters from the waste management unit boundary, but must also be on land which is owned by the facility owner. We modeled this alternative POC at 150 meters from the waste management unit boundary.

Table 1 summarizes the MSWLF designs that we assumed would meet the performance standard at both POCs. The Proposal does not explicitly require these designs, but we assigned designs to actual landfills based on their estimated releases. If the most stringent design would not allow the MSWLF to meet the design goal, we assumed the landfill would trigger corrective action. The majority of landfills are not assigned additional requirements beyond the general facility standards (i.e., they can meet the performance standard under baseline conditions). The fraction assigned to the more expensive designs is higher for the Proposal with the 10-meter POC than with the 150-meter POC because under this scenario compliance with the design goal is assessed closer to the waste unit boundary; little attenuation or dilution of releases can occur under this scenario so more landfills exceed the design goal.

The Proposal also includes general facility standards that are not dependent on the performance standard. These include post-closure care, ground-water monitoring, gas monitoring, and run-on and run-off controls.

Table 1		
SUMMARY OF DESIGNS ASSIGNED TO NEW LANDFILLS TO MEET DESIGN GOAL		
Design	Percentage of Units	
	10-Meter POC	150-Meter POC
Unlined/Vegetative Cover	61%	79%
Unlined/Synthetic Cover	11	9
Synthetic Liner/ Synthetic Cover	28	12

REGULATORY ALTERNATIVES

In addition to the proposed rule, three regulatory alternatives were analyzed in this RIA. The regulatory alternatives allow for a cost and benefit comparison of the proposed rule to other regulatory scenarios.

Alternative 1 is more stringent than the Proposal. It requires backup systems to ensure that leachate generation is minimized and that any leachate generated is collected. To this end, the Alternative calls for a composite cover system at closure for both new and existing units. New MSWLFs must all include a redundant containment system, similar to that specified for hazardous waste landfills under Subtitle C of the Resource Conservation and Recovery Act (RCRA). The system includes two synthetic layers, with leachate collection systems above each synthetic, and a supporting clay layer to delay leachate migration if leachate escapes the two synthetic layers.

The ground-water monitoring sampling and testing procedures are also more elaborate than under the Proposal. The detection monitoring program described in 40 CFR 264 is used, instead of the scheme in the Proposal. All requirements in the Proposal that are not linked to the performance standard are also imposed on landfills under this option. These include corrective action, gas monitoring, and post-closure care.

Alternative 2 imposes the same general facility standards on landfills that the Proposal does, but, instead of linking controls to a performance standard based on risk, this Alternative categorizes landfills according to their potential to generate leachate and assigns designs to prevent releases. MSWLFs in settings with a high potential for releases (e.g., a very wet climate) must have designs that will minimize the potential for releases into the ground water.

The two major criteria used to assign designs are that the cover must minimize infiltration into the waste after closure, and any containment and leachate collection systems must prevent releases to the underlying aquifer during the active life of the landfill. Using these criteria and several assumptions described in Chapter IV of the RIA, we assigned landfills to one of seven designs, presented in Table 2. These designs are not specifically required under this Alternative, but for modeling purposes we simulated landfill performance under the Alternative and developed designs that we estimated would meet the criteria. The most common design is also the most expensive: the synthetic liner/synthetic cover with a leachate collection system was assigned to 56 percent of the landfills.

Table 2			
SUMMARY OF DESIGNS ASSIGNED TO SURVEYED LANDFILLS			
Alternative 2			
<u>LCS</u>	<u>Containment</u>	<u>Cover</u>	Percentage of <u>MSWLFs</u>
No	Unlined	Vegetative	18%
No	Unlined	Synthetic	2
No	Clay	Vegetative	5
Yes	Synthetic	Vegetative	8
Yes	Synthetic	Synthetic	56
Yes	Unlined	Vegetative	4
Yes	Unlined	Synthetic	8

Corrective action is also required under this Alternative if the designs do not prove adequate to prevent releases from triggering a response.

Alternative 3 is the least stringent option: it imposes no design standards on landfills and no general facility standards. The only requirements are for ground-water monitoring during the active life, post-closure care (including ground-water monitoring), and corrective action as necessary. The emphasis of

this option is on response to releases instead of prevention. This Alternative is similar to the statutory minimum described in the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA, except that no location standards are included.

ANALYTICAL METHODOLOGY

The RIA includes three major analytical components: cost, economic impact, and risk and resource damage. Our methodology for analyzing each of these components is described briefly below and in greater detail in Chapter IV.

Cost

The basis of the cost analysis is a facility design and cost model that takes selected input variables and produces the specifications and costs for a municipal solid waste landfill. This design and cost model first identifies the various steps involved in designing, constructing, operating, and closing a landfill; combines this information with data on costs and fees for the components; and estimates the total cost of the landfill. The cost components include a wide range of items such as land, clearing, excavation, equipment, labor, liner materials, and ground-water monitoring wells.

We estimated the cost of constructing and operating a "baseline" landfill--one designed in accordance with current criteria and best engineering practices, but excluding many preventive features contemplated in this rulemaking. We also estimated the costs of building and operating landfills under each of the regulatory options. The incremental costs between the regulated units and the baseline units form the basis for the cost and impact results.

We made two adjustments to incremental costs to take account of states that have programs that already require ground-water monitoring or containment systems. EPA identified 24 states with equivalent monitoring programs, so, for the 2,702 landfills in those states, we excluded capital costs for ground-water monitoring wells under each option. EPA also concluded that 22 states (with 3,657 landfills) had containment system requirements that would be acceptable under the Proposal, so landfills in those states that were assigned a synthetic liner and LCS did not incur the incremental costs. The benefits of the containment system were not similarly adjusted.

As described in Chapter III, the Proposal calls for a two-phased ground-water monitoring program. We modeled a three-phased program and the list of individual constituents for which facility operators must monitor during the early stages of facilities' lifetimes is much more extensive under the Proposal than in our modeling. As explained in the Note to Readers, the magnitude of ground-water monitoring costs under the Proposal is, therefore, understated.

Using the cost model, we estimated compliance costs for approximately 10 percent of all MSWLFs, those that responded to the landfill facility survey. Cost estimates were made for existing landfills and for replacement landfills meeting the specifications of the Proposal and each alternative. A combined cost estimate, that averaged together costs at the existing facility plus the new replacement facility, was then made for each landfill. The combined cost estimates were scaled up to the universe of all MSWLFs to estimate national compliance costs.

Economic Impact

The economic impact analysis assesses the impacts of the regulatory options on those who will face increased costs and analyzes how those impacts will be distributed. Because 81 percent of all landfills that handle MSW are owned by local governments, the municipalities that own these landfills will bear the initial economic impacts of revised Subtitle D regulations. These governments will then pass increased costs on to their own citizens (and to neighboring governments that might also use the landfill) in the form of increased taxes or fees, or decreased services of other types if the community is operating under tight budget constraints. Ultimately, the households that use the landfill to dispose of their waste will pay the increased costs of landfill operations. Approximately 15 percent of all MSWLFs are owned by private operators. The MSW handled by these landfills comes from the governments or households that contract for the landfills' services. Thus, even in the case of private ownership, the governments and households served will ultimately bear the cost and impacts of new regulations.

Risk and Resource Damage

The Subtitle D Risk Model was developed to evaluate risk and resource damage, assess the adverse effects of releases from MSWLFs on human health and resource value, and examine the effectiveness of the regulatory options in reducing these impacts. The model builds directly on the Liner Location Risk and Cost Analysis Model, developed to address these same questions for land disposal units regulated under Subtitle C of RCRA. It is a

dynamic model that simulates environmental fate and transport and dose-response as deterministic processes, while simulating containment system failures stochastically. The model focuses on ground water as the environmental medium of concern; it does not evaluate the effects of contamination to surface water and the ecosystem.

Our basic approach was to use the Subtitle D Risk Model to simulate risk and resource damage first in the baseline, and then under each of the regulatory options being considered. We modeled risk and resource damage in hundreds of scenarios that represent unique combinations of landfill size, climatic and hydrogeologic setting, and exposure distance. Using preliminary results from EPA's Municipal Landfill Survey and a separate mapping effort, we then estimated the frequency with which each scenario occurs in the nationwide population of MSWLFs, and weighted the results for each scenario to reflect its frequency of occurrence.

For the benefits analysis we assumed that all facilities are new. For the baseline, we modeled a landfill that operates for 20 years. To simulate the effectiveness of the regulatory options, we assumed that a new landfill is constructed at the same site and is designed and operated throughout its lifetime according to the requirements of the option being considered. We did not model the effectiveness of the regulatory options at existing units. We assumed that all MSWLFs would comply with a 10^{-5} design goal chosen from the allowable range of 10^{-4} to 10^{-7} . If the design goal were set elsewhere in the 10^{-4} to 10^{-7} range, the results of the cost and effectiveness analysis would change. We used 300-year average maximum individual risk levels (rather than an alternative instantaneous measure of maximum lifetime risk) to assess compliance with the standard at the compliance point. As a result of the risk-averaging procedure, the need for containment systems given the design goal tends to be understated for the Proposal. Instantaneous concentrations may peak above levels causing a 10^{-5} risk, but the averaging procedure smooths out those peaks. As in the cost analysis, we assumed that the compliance point for the Proposal is 10 meters from the landfill unit unless the state approves use of an alternative boundary that we assumed would be the maximum distance allowed by the Proposal, 150 meters from the unit.

The Proposal and all the alternatives are analyzed with an extended post-closure care requirement. The Proposal requires a two-phased post-closure care period. The first phase lasts 30 years and includes maintenance of the landfill and cover plus ground-water and gas monitoring. The second phase requires ground-water and gas monitoring (at a minimum) for a duration to be set by the state.

In the benefits modeling, extended care continues for 80 years after the end of the active life, and includes maintenance of the cover (only for the first 30 years), ground-water monitoring, and corrective action if necessary. We assumed that synthetic cover system components are maintained and replaced if necessary only until the end of the first 30 years of post-closure care. For all the regulatory options we assumed that corrective action would be triggered if 300-year average individual risk exceeds 10^{-5} at the POC; again, use of an average risk figure will tend to underestimate the number of landfills that would trigger corrective action under all the options.

We modeled eight constituents of concern, which were selected based on their observed median concentrations in MSWLF leachate, their toxicity, and other factors. We report risks as average maximum individual risk (i.e., the most exposed individual lifetime risk averaged over the 300-year modeling period). By using data on the size of populations drinking from wells, population risks are also estimated. Resource damage is measured as the present value of the cost to provide water to users whose supply is contaminated by releases from landfills. A water supply is considered contaminated when constituents exceed the lower of regulatory limits under the Safe Drinking Water Act or taste and odor thresholds.

RESULTS

Costs

The combined annualized costs of the five options range from \$419 million for Alternative 3 up to \$3,341 million for Alternative 1. The Proposal falls near the lower end of this range at \$880 million using the 10-meter POC and \$691 million using the 150-meter alternative POC. The costs with and without corrective action are summarized in Table 3. Corrective action has the greatest effect on costs for the Proposal and Alternative 3. These are the options in which less stringent design standards are modeled and, therefore, more corrective actions are necessary. Corrective action does not change the relative ranking of the options, however. The relative costs across options are affected by the stringency of the requirements only, since the size distribution across units and the range of remaining lives are constant across options.

Table 3

COMBINED ANNUALIZED COSTS: NATIONAL ESTIMATES
(dollars in millions)

<u>Option</u>	<u>No Corrective Action</u>	<u>Including Corrective Action</u>	<u>Percentage of Total Cost Contributed by Corrective Action</u>
Proposal (10-meter POC)	\$ 782.2	\$ 880.0	11.1%
Proposal (150-meter POC)	562.0	691.4	18.7
Alternative 1	3,268.6	3,341.0	2.2
Alternative 2	1,336.9	1,426.9	6.3
Alternative 3	117.1	419.4	72.1

The Proposal imposes different costs on units according to the likelihood that the unit will meet the design goal at the relevant point of compliance. In order to compare the effect of this strategy with the regulatory alternatives, we estimated the median cost per unit for landfills across all five regulatory options. Table 4 presents the annualized combined costs on a per-unit basis. Median costs range between \$20,000 and \$211,000. The table also provides maximum costs per landfill, which range as high as \$18 million per year under Alternative 1. Minimum costs per landfill across all options are less than \$8,000 per year.

Table 4

COMBINED ANNUALIZED COSTS: COSTS PER LANDFILL
(including corrective action)
(thousands of dollars)

<u>Statistics</u>	<u>Option</u>				
	<u>Proposal (10-meter POC)</u>	<u>Proposal (150-meter POC)</u>	<u>Alternative 1</u>	<u>Alternative 2</u>	<u>Alternative 3</u>
Median	\$ 43.6	\$ 38.8	\$ 210.8	\$ 64.4	\$ 20.4
Maximum	5,555.1	3,106.2	18,087.0	7,036.4	1,048.6
Minimum	1.5	1.4	7.3	1.4	0.3

Table 5 summarizes the incremental cost per ton of waste managed across the options and shows not only the range of incremental costs, but how tightly clustered landfills are across the cost categories. The Proposal (10-meter POC) imposes maximum costs per ton of \$40.61 (see Table 6), but 95 percent of the landfills have incremental costs of less than \$25. The median cost per ton is \$11.01 using this compliance point. The Proposal with the 150-meter POC in effect has a similarly large cluster below \$25 per ton, but the maximum costs are higher than under the 10-meter POC. The reason for the higher extreme is the higher cost of corrective action when the corrective measures do not begin until the plume reaches the POC 150 meters from the unit. Under the 10-meter POC, corrective action would begin when the threshold is exceeded at the unit boundary (i.e., 10 meters from the unit in this analysis).

Table 5					
COMBINED INCREMENTAL COSTS PER TON BY OPTION					
(corrective action included)					
Percentage of MSWLFs in Range					
Cost Ranges (cost per ton)	Proposal (10-meter POC)	Proposal (150-meter POC)	Alt. 1	Alt. 2	Alt. 3
>\$100	0%	0%	1%	0%	0%
\$75-\$100	0	1	16	0	0
\$50-\$75	0	1	32	0	1
\$25-\$50	5	1	27	32	18
\$10-\$25	49	45	21	39	3
\$1-\$10	45	51	3	28	67
\$0-\$1	1	1	0	1	11

Table 6					
COMBINED INCREMENTAL COSTS PER TON BY OPTION					
Descriptive Statistics					
	Proposal (10-meter POC)	Proposal (150-meter POC)	Alt. 1	Alt. 2	Alt. 3
Median	\$11.01	\$ 9.54	\$47.58	\$15.62	\$ 5.17
Maximum	40.61	81.39	108.11	48.38	54.45
Minimum	0.76	0.75	4.01	0.75	0.06

Alternative 1 imposes costs across a broader range, from a maximum incremental cost per ton of \$108.11 to a minimum of \$4.01. Compared to the Proposal, the distribution has shifted up, as shown by the median, which more than quadrupled to \$47.58. Alternative 2 is more expensive than the Proposal for the median landfill, with the median cost per ton of \$15.62.

Alternative 3 has incremental costs similar to the Proposal, but the distribution is more spread out because corrective action plays a larger role in the total costs and pushes the distribution upwards.

Economic Impacts

The economic impact analysis begins with the calculation of three measures to assess the impacts of the regulatory options. The first measure, incremental regulatory cost as a percentage of total municipal expenditures (CPE), focuses on the impacts of the options on municipal budgets. Communities are classified as experiencing severe impacts if CPE exceeds 1 percent. The remaining two measures, annual incremental costs per household (CPH) and costs per household as a percentage of median household income (CPMHI), focus on the impacts of the regulation on households, since households are the primary generators of MSW and ultimately pay for its disposal. The analysis classifies household impacts as severe if CPH exceeds \$220 per year or CPMHI exceeds 1 percent.

The results of the economic impact analysis indicate that most of the options will dramatically increase communities' expenditures for MSW disposal. Although the percentage increases in MSW disposal costs are large for many communities, these costs still comprise only a small fraction of communities' total budgets. Table 7 indicates the percentage of communities and people whose CPE will exceed 1 percent under the Proposal and each of the three alternatives. Under Alternative 1, two-thirds of the communities have CPE exceeding 1 percent, while under Alternative 2, 33 percent of all communities fall in this category. The Proposal has still lower impacts using this measure, with 16 percent of all communities severely affected under the 10-meter POC and 11 percent under the 150-meter POC.

Because the heaviest impacts fall on small MSWLFs that serve small communities, the percentage of the total U.S. population that resides in these communities is much smaller than the percentage of communities affected. In addition to being small, two out of three communities facing an incremental CPE greater than 1 percent are in rural areas (e.g., have population densities below 40 people per square mile).

Table 7

MUNICIPALITIES AND PEOPLE WITH REGULATORY COSTS
EXCEEDING ONE PERCENT OF CURRENT
COMMUNITY EXPENDITURES

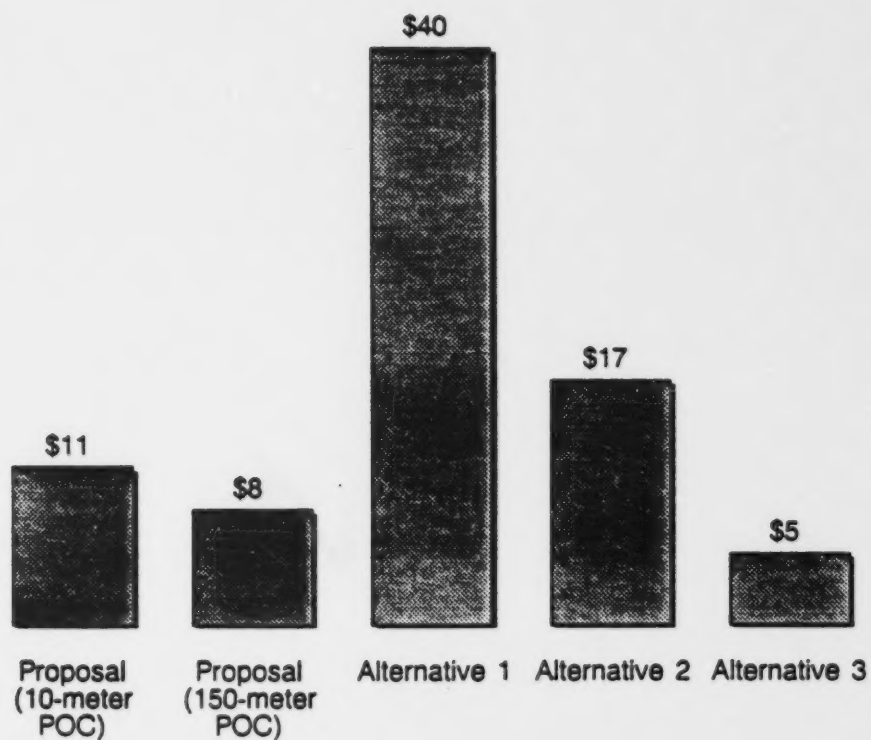
Option	Municipalities		People	
	Number	Percentage of Total	Number (millions)	Percentage of Total
Proposal (10-meter POC)	4,742	16%	15.5	7%
Proposal (150-meter POC)	3,293	11	9.6	4
Alternative 1	19,661	68	79.5	34
Alternative 2	9,491	33	28.7	12
Alternative 3	2,852	10	7.1	3

Source: TBS calculations.

Several factors will tend to mitigate the actual impact of the options on communities with high CPE. One important factor is the relatively small proportion of the municipal budget that is usually devoted to MSW disposal. Preliminary data from EPA's MSWLF survey indicate that the typical community currently spends approximately 0.5 percent of its budget on solid waste disposal. Although CPE greater than 1 percent indicates that MSW disposal expenditures may double in many communities after regulation, these expenditures will still represent less than 2 percent of the total municipal budget in most communities. For comparison, the average community in the United States currently spends 36 percent of its budget on education, 5 percent for police protection, 3 percent for sewage disposal, 2 percent for fire protection, and 1 percent for sanitation services other than sewage, including solid waste collection and disposal and street cleaning. Although it may be difficult for communities to cope with large percentage increases in MSW disposal costs in the short run, once the initial adjustment is made, these costs should be easier for communities to absorb because they comprise a very small portion of communities' total budgets.

Figure 1 summarizes the impacts of the regulatory alternatives on households. Average incremental CPH across the entire nation ranges from \$5 under Alternative 3 to \$40 under Alternative 1. Incremental CPH under the Proposal (10-meter POC) averages \$11 and declines to \$8 using the 150-meter POC. In 90 percent of the communities, current solid waste disposal costs per household are less than \$25 per year (excluding collection and transportation costs). Thus, even under the least expensive alternative, CPH could increase by 50 percent for many communities.

Figure 1
Average Incremental Cost per Household Across the Entire Nation
(dollars per year)



Source: TBS calculations.

For this analysis, the threshold level for severe impacts on households is \$220 per year. This threshold is only exceeded under Alternative 1 and the Proposal if the 150-meter POC is used. In each case, the communities affected are in rural areas. For all the other options, the number of communities where CPH exceeds even the more moderate threshold of \$100 per year is less than 0.5 percent. Under Alternative 1, however, 23.5 percent of the communities experience increases in CPH of more than \$100 per year.

In general, smaller communities have higher impacts because they are served by smaller landfills, which incur the largest incremental costs per ton under all the options. A majority of communities with CPH above \$100 have fewer than 5,000 people. Thus, some smaller communities could reduce the burden of regulation by participating in larger regional landfills.

Cost per household as a percentage of MHI is relatively low across all of the regulatory options. EPA's construction grants program has used a threshold of 1 percent for this measure to identify communities that might experience difficulties affording new wastewater treatment facilities. In our analysis, this threshold was only exceeded under Alternative 1 and the Proposal (150-meter POC); even under these options, no more than 1.1 percent of all households fall into the high impact category.

The analysis also assumes that communities set aside money to provide for post-closure care during the operating life of the landfill. Although private operators must do this, publicly-owned landfills may have opportunities to reduce impacts (depending on how they meet financial responsibility requirements) by deferring payment for post-closure care until the costs are actually incurred.

The impact analysis also evaluates the financial capability of municipalities to cover the projected regulatory costs. The results of the analysis indicate that for some communities their practicable capability to implement the regulations will be strained. Eleven percent of communities that have weak financial capability will have high CPE (over 1 percent) for complying with the Proposal (10-meter POC). These communities, in particular, are most likely to experience difficulties affording the proposed revisions to the criteria.

Preliminary Regulatory Flexibility Analysis

As part of the economic impact analysis, we have conducted a preliminary analysis of impacts on small entities, particularly small governments, as required by the Regulatory Flexibility Act. The purpose of the analysis is to analyze impacts on small entities to determine whether or not a significant impact would be imposed on a substantial number of small entities from this regulation. Figure 2 illustrates impact levels across community sizes for one of the three economic impact measures, CPH (cost per household). This figure shows that differential impacts do occur and that greater impacts fall on small communities.

This analysis indicates that there is a differential impact, although not a significant impact, on a substantial number of small entities. As part of the final rulemaking, these differential impacts will be assessed in greater detail to determine whether they are significant enough to warrant consideration of regulatory alternatives for small entities.

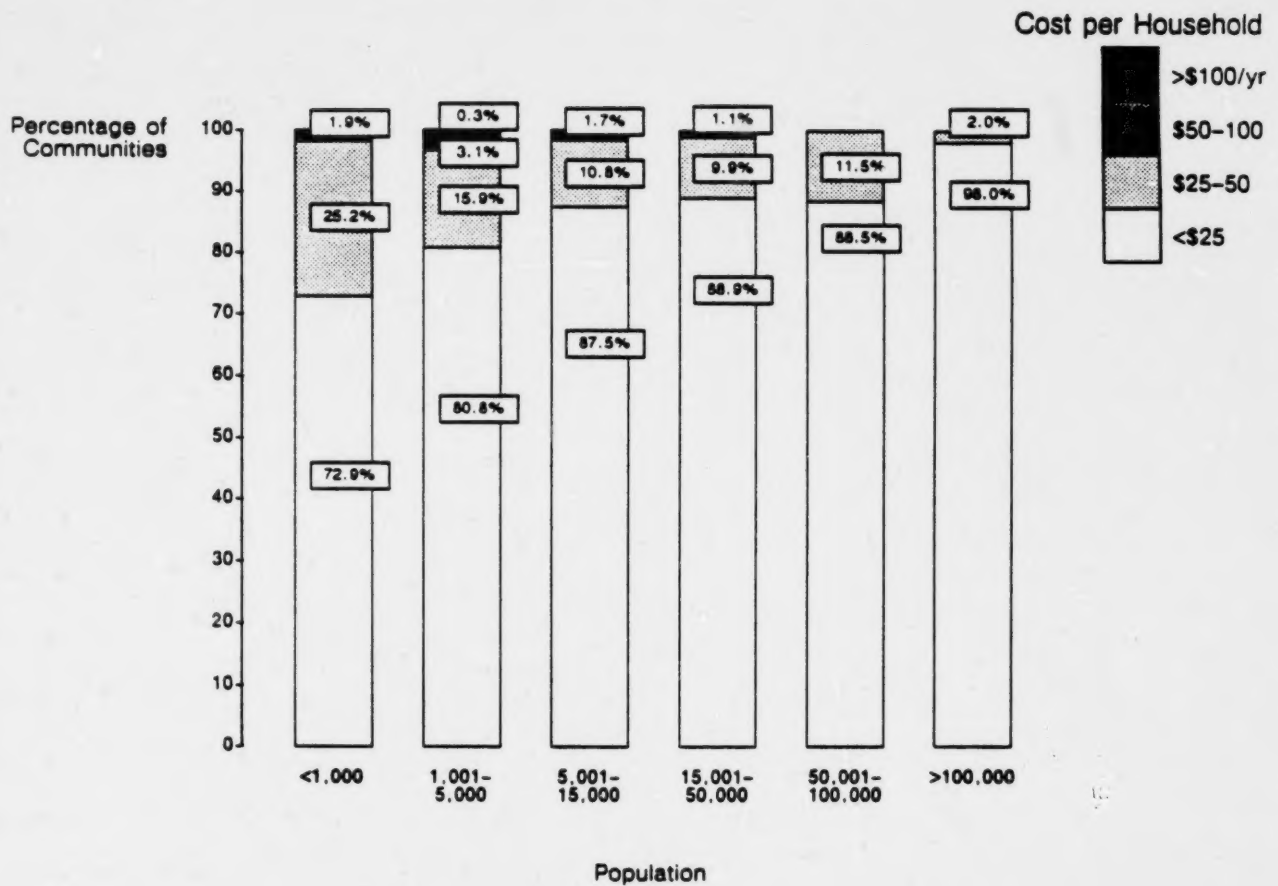
Risk and Resource Damage

The risk and resource damage results are summarized below, first for the baseline and then for the regulatory options. In the discussion of results, MEI (maximum exposed individual) risk is the 300-year average individual risk at the well closest to the landfill, as reported in the MSWLF survey. Population risk is expressed as the number of cases expected annually over the 300-year modeling period. Finally, resource damage is the cost expressed in present value terms to provide water to users whose supply is contaminated by releases from landfills.

Baseline Risk

MEI risk in the baseline ranges from zero to about 10^{-4} . About 60 percent of the landfills pose no risk. For approximately 54 percent of the landfills, we simulate zero risk because no drinking water wells are reported within one mile of the unit (we model risk out to a maximum well distance of about one mile). The remaining 6 percent have no risk because constituents do not reach the nearest well during the modeling period. A total of 6 percent of the landfills pose actual MEI risks (i.e., risk to a person exposed at the closest well) higher than 10^{-5} and a total of 17 percent of the landfills have MEI risk exceeding 10^{-6} . Less than one-tenth of a percent have risks higher than 10^{-4} . This risk distribution can be expected to shift toward higher risks if new wells are drilled near existing landfills or if new

Figure 2
 Cost per Household per Year for Proposed Rule (10-Meter POC)
 By Community Size



Source: TBS calculations.

landfills are sited near existing wells. The number of cancer cases expected annually over the 300-year modeling period, summed for 6,034 new facilities, is 0.0770.

Estimated risk is caused entirely by carcinogens, predominantly vinyl chloride; 1,1,2,2-tetrachloroethane; and dichloromethane. We believe that these pollutants are present in MSWLF leachate primarily as a result of disposing household hazardous waste, small quantity generator waste, and industrial solid waste.

Risk tends to be higher in the wetter climates and for the larger facilities, and tends to be lower at the more distant wells. No single factor is responsible for most of the variability; instead there is a complex interaction among the factors that govern leachate flux and flow through the underlying aquifer.

The baseline risk estimates were based on median levels of contaminants observed in leachate at actual landfills. To place an approximate upper bound on concentrations and risk, we determined the 90th percentile level of each constituent and compared it to the median. The 90th percentile concentrations of the three principal constituents contributing to risk are about one order of magnitude higher than their medians. Because all these constituents are carcinogens, and because cancer risk varies linearly with dose, we believe that the risk associated with the 90th percentile levels would be about one order of magnitude higher than that simulated using the median levels. This indicates that at 10 percent of the landfills, risks could be 10 times higher than our results indicate.

Baseline Resource Damage

Under the baseline modeling assumptions, the cost to replace contaminated ground water at landfills ranges from zero to over \$4 million (present value or PV) per landfill. Sixty-nine percent of landfills have replacement costs of \$200,000 or less. Because ground water in the vicinity of more than half of the landfills is not currently used, most contamination causes resource damage that has relatively low present value. For units where nearby populations currently use ground water, replacement costs can be high. Replacement costs exceed \$1 million (PV) for 13 percent of the landfills. About 29 percent of the landfills have no resource damage, indicating that pollutant levels in ground water did not exceed MCLs or taste and odor thresholds during the modeling period.

The median replacement cost is about \$79,000 (PV), and the total resource damage for 6,034 new landfills is about \$2.58 billion (PV).

Effectiveness of Regulatory Options

All the regulatory options reduce risk and resource damage from baseline levels. Table 8 summarizes the risk and resource damage reduction capabilities of each regulatory option, based on our analysis. The first pair of columns shows the number of cases avoided annually. The second pair of columns shows the resource damage totals, added across all 6,034 new facilities, and the damage reduction attributable to each regulatory option.

Table 8				
RISK AND RESOURCE DAMAGE REDUCTION FOR 6,034 NEW FACILITIES				
Regulatory Scenario	Population Risk		Resource Damage (billions of dollars)	
	Cases per Year	Reduction (cases/year)	Resource Damage (PV)	Damage Reduction (PV)
Baseline	0.0770	--	\$2.58	--
Proposal (10-meter POC)	0.0210	0.0560	1.27	\$1.31
Proposal (150-meter POC)	0.0227	0.0543	1.60	0.98
Alternative 1	0.0086	0.0684	0.41	2.17
Alternative 2	0.0105	0.0665	0.57	2.01
Alternative 3	0.0216	0.0554	1.57	1.01

Of all the options considered, Alternative 1 is the most effective in reducing both risk and resource damage. Alternative 1 imposes the most stringent containment system design on all landfills, and it eliminates 89 percent of the baseline cancer cases and 84 percent of the total resource damage. Alternative 2, which requires landfills to comply with performance standards based on time of travel to the uppermost aquifer and infiltration of water through the cover, is almost as effective as Alternative 1.

The Proposal, using either compliance point, and Alternative 3 are nearly indistinguishable in terms of risk reduction. Reductions in the annual number of cancer cases range between 71 and 73 percent. Among these three regulatory options, the Proposal with a 10-meter POC reduces risk most effectively, followed by Alternative 3 and then the Proposal using the 150-meter POC. The ranking is the same for resource damage, with reductions in total resource damage ranging between \$980 million for the 150-meter POC and \$1.3 billion using the 10-meter POC (38 and 51 percent reductions, respectively, from the baseline).

Alternatives 1 and 2 are more effective than the Proposal and Alternative 3 because the latter two target only the high-risk landfills (i.e., those with MEI risks of 10^{-5} or higher at the compliance point). According to our analysis, only 39 percent of the landfills trigger design-goal-based requirements under the Proposal (10-meter POC), and only 21 percent are affected when the compliance point is further from the landfill. Under Alternative 3, 39 percent of the units trigger corrective action. Alternatives 1 and 2, on the other hand, impose more stringent design standards on all or most of the landfills. Nevertheless, all the options substantially reduce the occurrence of MEI risks greater than 10^{-5} .

COST-EFFECTIVENESS

Cost-effectiveness is a convenient summary measure of the relative effectiveness, given the compliance costs, of the Proposal and the regulatory alternatives. The measures of effectiveness are reductions in human health risk and in resource damage, calculated as the cost to replace contaminated water supplies for current or potential users.

In order to compare risk reduction with incremental costs, we must match both measures to capture the same effects over the same period of time. The Risk Model estimated the number of cases that would occur for each landfill over each year of the simulation. Aggregating to the population, the model calculated the total number of cases per year for the baseline and each regulatory option. To compare the number of cases with costs, we summed the number of cases over the 300-year period.

In addition to risk reduction, the model also estimates reductions in resource damage in present value terms. We should emphasize that these two measures of benefits, risk and resource

damage, are mutually exclusive and cannot be added together. They are best viewed as alternative measures of benefit that emphasize different aspects of the benefits.

For costs, we calculated the present value of costs for a set of 6,034 new landfills and for the subset of landfills with wells within one mile. We did not factor in existing unit costs in order to be comparable to the benefits methodology. The analysis of costs for landfills with wells illustrates a scenario that may occur in the future where virtually all landfills have nearby drinking water wells. In the current set of surveyed landfills, only 46 percent reported wells within one mile. Both costs (total and with wells) are presented to illustrate the total cost-effectiveness of the options and then the incremental cost-effectiveness of reducing risks at landfills that currently have wells.

The cost estimates generated for this analysis incorporate costs for a range of activities associated with the operation of an MSWLF. Some of these costs will have effects on media other than ground water, but the benefit measures are restricted to ground water. Therefore, in the cost-effectiveness calculations we are assigning a higher cost than is appropriate for protecting ground water. The ground-water protection costs dominate the incremental cost estimates, however, so the cost-effectiveness ratios are reasonable estimates.

Table 9 combines estimates of risk reduction and incremental costs for new units. The estimates are all summed over the 300-year period with cases avoided aggregated over the modeling period and costs in present value terms.

Table 9					
COST PER CASE AVOIDED					
New Units Only; 300-Year Benefit Period					
(dollars in millions)					
	Cases Avoided (cases/year X 300 years)	Incremental Cost (PV)		Cost per Case Avoided	
		All Landfills	Landfills with Wells ¹	All Landfills	Landfills with Wells ¹
Proposal (10-meter POC)	16.8	\$11,899	\$ 5,558	\$ 708	\$ 331
Proposal (150-meter POC)	16.3	8,939	4,296	548	264
Alternative 1	20.5	54,548	23,641	2,661	1,153
Alternative 2	20.0	21,739	9,759	1,087	488
Alternative 3	16.6	6,065	2,830	365	170

¹Landfills with a drinking water well within one mile.

The Proposal (10-meter POC) has costs per case avoided of \$703 million, higher than the Proposal with the 150-meter POC and Alternative 3. Alternatives 1 and 2 are much less cost-effective.

Table 10 presents estimates for avoided resource damage and cost at new units. To compare costs with benefits, we calculated a ratio between the two measures. When the ratio is less than 1, costs exceed benefits. The ratio is less than 1 for all the options. Alternative 3 has the best ratio, but does not provide as much RD reduction as the Proposal (10-meter POC), Alternative 1, or Alternative 2.

Table 10			
NET BENEFIT OF RESOURCE DAMAGE IMPROVEMENTS			
New Units Only			
(dollars in millions)			
	Avoided Resource Damage (PV)	Incremental Cost (PV)	Benefit/Cost
Proposal (10-meter POC)	\$1,310	\$11,899	0.110
Proposal (150-meter POC)	980	8,939	0.110
Alternative 1	2,170	54,548	0.040
Alternative 2	2,010	21,739	0.092
Alternative 3	1,010	6,065	0.167

The costs per case avoided from new landfills are relatively high in an absolute sense, but the most useful aspect of the analysis is the indication of the relative effects of the different options. Given the current modeling assumptions and the regulatory alternatives, the Proposal is dominated by Alternative 3 in both cost per case avoided and benefit-cost ratio for resource damage improvements. Each option is ranked in Table 11. We can conclude that Alternative 3, with its emphasis on correcting releases from leaking landfills, is the best option from a pure cost-effectiveness standpoint. Reliance on a remedial approach, however, introduces more uncertainty in the timing, effectiveness, and cost of corrective action, which may not be well reflected in these estimates.

Table 11
SUMMARY OF COST-EFFECTIVENESS

Risk				Resource Damage		
PV Cost per Case Avoided (dollars in millions)						
Rank	Option	All Landfills	Landfills with Wells	Rank	Option	Cost/Benefit
1	Alternative 3	\$ 365	\$ 170	1	Alternative 3	0.167
2	Proposal (150-meter POC)	548	264	2	Proposal (150-meter POC)	0.110
3	Proposal (10-meter POC)	708	331	3	Proposal (10-meter POC)	0.110
4	Alternative 2	,087	488	4	Alternative 2	0.092
5	Alternative 1	2,661	1,153	5	Alternative 1	0.040

LIMITATIONS

There are several important caveats to the cost, economic impact, risk, and resource damage results presented in this RIA. Compliance costs represent an upper-bound estimate because some factors that would reduce costs were not analyzed. It is unlikely that each of the existing 6,034 MSWLFs will have a replacement landfill in perpetuity (as assumed in this analysis) due to factors like regionalization, recycling, and resource recovery. We did not assess use of larger, regional landfills; waste shifts to resource recovery facilities; and better siting of new landfills in "good" locations. These factors were not considered in the analysis because they would require simulation of site-specific, local decisions that are difficult to analyze.

By participating in larger regional landfills with other local governments, smaller communities can take advantage of substantial economies of scale, and thus reduce compliance costs. The economies of scale will likely remain positive even with additional costs due to transfer stations and increased transportation distances. Although these economies of scale exist, there are many local, noneconomic factors (e.g., political, technical) that enter into landfill siting decisions that may actually restrict regionalization.

Future waste shifts to resource recovery facilities will divert the volume that must be landfilled and thus costs presented in this report will tend to be overstated. It is likely that solid waste combustion will become more attractive in the future due to competitive costs with landfilling or favorable environmental conditions at a given site. However, a report prepared for EPA (Office of Solid Waste, Characterization of Municipal Solid Waste in the United States, 1960 to 2000, Franklin Associates, Ltd., July 1986 and the March 1988 update) estimates that the volume of land disposed solid waste will likely remain constant over the next 15 years. The report indicates that resource recovery could divert as much as 18 percent of the solid waste stream away from land disposal given future population growth and increases in the volume of solid waste generated. Alternatives to land disposal other than energy recovery also exist (e.g., recycling, composting). These programs, although often successful due to their inherent flexibility and cost-effectiveness, have historically diverted only modest amounts of municipal solid waste from the waste stream.

A final caveat to the cost analysis is described in the Note to Readers and relates to the costs for ground-water monitoring. For phase one monitoring under the Proposal, the cost per sample estimates used in the RIA are too low. The actual costs per landfill are, therefore, underestimated.

We also have several caveats related to the risk analysis. The risk and resource damage modeling includes considerable uncertainty. The model components that introduce the most uncertainty are those that predict: (1) leachate quality for trace organics, (2) the probability and consequences of containment system failure, (3) the cost and effectiveness of corrective action, and (4) the human health risk resulting from exposure to toxic substances (i.e., the dose-response models).

The risk analysis considers only the current population that is using the ground water as a drinking water source. Future population growth would increase the risk reduction estimates presented in this RIA. It is likely that, in the future, greater numbers of people and wells will be located near MSWLFs. This may be offset if regionalization occurs so that the total number of landfills is reduced. Future population growth and a corresponding increase in solid waste generation which may be land disposed would also increase compliance costs from the current estimates.

The risks presented in this RIA are limited to those attributable to drinking contaminated ground water. Other risks from MSWLFs were not analyzed (e.g., surface water contamination, subsurface gas, risks to the ecosystem). Analyzing these risks would result in greater risk reduction than currently estimated. The aggregate costs include some of the controls that would prevent these other forms of risk, although the bulk of the compliance costs are for requirements that serve to protect the ground water from leachate contamination.

One other concern is that risk reduction is only modeled at new units. Additional risk reduction is also likely at existing units. If existing units were included, risk and resource damage avoided would increase.

Finally, the modeling period used in the risk analysis is 300 years. Greater risk reduction would be obtained if this period was extended.

Many assumptions, like those discussed above, enter into the risk analysis. Thus, strong reliance on the absolute risk or cost-effectiveness estimates without full realization of the limitations of the analysis should be avoided. In general, relative comparisons of the risk estimates across regulatory options are more appropriate than judgments based on the absolute estimates for a given option.

I. INTRODUCTION

THE FEDERAL ROLE IN SOLID WASTE DISPOSAL

Since 1979, the federal government has had criteria (40 CFR Part 257) for classifying solid waste disposal facilities as either sanitary landfills or open dumps. These criteria fall under Subtitle D of the Resource Conservation and Recovery Act (RCRA) and include performance standards for these disposal facilities. Facilities failing to meet the criteria are classified as open dumps and must be closed or upgraded.

The Subtitle D program was designed as a cooperative effort between federal, state, and local governments; the federal role was to establish minimum standards and provide implementation funding to states. This funding was cut off, however, in 1981, when the focus of RCRA turned to hazardous waste issues primarily under Subtitle C.

The Hazardous and Solid Waste Amendments of 1984 (HSWA) marked the federal government's reintroduction into the Subtitle D arena. Section 4010 of HSWA required the Environmental Protection Agency (EPA) to promulgate revisions to the criteria for facilities that may receive household hazardous waste or small-quantity generator waste. The revised criteria must protect human health and the environment and, at a minimum, should:

- Require ground-water monitoring,
- Establish criteria for the acceptable location of new or existing municipal solid waste landfills (MSWLFs), and
- Provide for corrective action as appropriate.

Finally, in developing the criteria, EPA may take into account the "practicable capability" of MSWLF owners/operators.

THE NATURE OF THE PROBLEM

The new federal initiative emerged out of Congress's concern over the quantity of hazardous wastes and other dangerous materials that are placed in Subtitle D landfills. These wastes may include household hazardous wastes; small-quantity generator

wastes; or illegally dumped hazardous waste. In addition, 184 of the 850 sites listed or proposed for listing on the National Priority List (compiled for the Superfund program as of May 1986) are MSWLFs. EPA has assessed many of these concerns in its Report to Congress, cited in Chapter II of this report.

The Subtitle D universe consists of MSWLFs, industrial landfills, land application units, surface impoundments, and waste piles. However, EPA currently has adequate data for regulatory decisions only on MSWLFs. EPA is gathering data on other Subtitle D facilities and will assess the need to regulate these facilities as this information becomes available. Thus, this rulemaking applies only to MSWLFs. Preliminary results of a survey effort indicate that there are 6,034 MSWLFs that may receive household hazardous waste and small-quantity generator waste.

REQUIRED ANALYSES

Executive Order 12291 requires federal agencies to prepare a regulatory impact analysis (RIA) for all "major" regulations, defined as those expected to have an annualized cost of more than \$100 million. Because the proposed modifications to the Subtitle D criteria will entail costs of at least this magnitude, EPA has prepared this draft RIA.

An RIA typically evaluates regulatory options by considering their costs, effectiveness, economic impact, cost-effectiveness, and, where possible, net social benefits. This RIA performs the evaluation in terms of the two charges from Congress: that the revisions protect human health and the environment, and that they consider the practicable capability of MSWLF owner/operators.

To assess the effects on human health and the environment, the incremental effects of regulatory options in reducing human health risk and resource damage are evaluated. Both risk and resource damage measures are based on improvements in ground-water quality. Human health risks are measured in terms of risk to the most exposed individual (the individual exposed at the nearest ground-water well) and risk to the population that takes into account all exposed people within a fixed distance (i.e., one mile) from the MSWLF. Resource damage is measured as the cost of an alternative drinking water supply to replace the contaminated ground water.

The practicable capability issue is addressed by measuring the incremental costs of the regulatory options and comparing these costs to current MSWLF operating costs, to current total

community expenditures, and to median household income. The affordability of each option is measured relative to the financial capability of the municipalities that own or use the facilities. Each of these components of the analysis is discussed in more detail in Chapter IV, Methodology.

EPA is also required under the Regulatory Flexibility Act of 1980 to assess whether the regulation will have a "significant economic impact on a substantial number of small entities." If a rule does have such an impact, EPA must then complete a regulatory flexibility analysis (RFA). The entities of primary concern for this proposed rulemaking are small governmental jurisdictions, defined in the Act as governments of a district with a population of less than 50,000. Since more than half of the MSWLFs are owned by governments of this size, a different cutoff may be appropriate. Alternatives to the size criteria are discussed in Chapter V, along with criteria for "significant economic impact" and "substantial number."

OUTLINE OF THE REPORT

This report contains six chapters. Chapter II describes the background for the current regulatory Proposal. We describe the current regulatory requirements for landfills (the term "landfill" is used interchangeably with MSWLF); the characteristics of landfills that will be subject to new regulatory requirements (including their size, location, and ownership); and the design and operating practices of existing landfills.

Chapter III presents the regulatory options, including the proposed revisions to the criteria and the regulatory alternatives. This regulatory impact analysis was prepared with the best information available describing the proposed rule. Several requirements have changed recently and some of these changes had to be analyzed qualitatively in this report. We will complete a quantitative analysis of the regulatory options, plus any subsequent changes, in the final RIA.

In Chapter IV we present the methodology for the cost analysis, economic impact analysis, and the risk and resource damage analysis. Chapter V follows the same organization and presents the cost results, economic impacts, a discussion of the impacts of the options on small entities, and risks and resource damage for each regulatory option.

Chapter VI combines the cost and risk and resource damage estimates to assess the cost-effectiveness of the various options.

II. BACKGROUND

This chapter begins with a summary of existing federal and state regulations on Subtitle D facilities. The next section provides descriptive characteristics--number, size, remaining life, ownership, location, operating practices--of existing MSWLFs that would potentially be subject to any new regulations proposed by EPA.

CURRENT REGULATORY REQUIREMENTS

Federal Regulations

As described in Chapter I, EPA promulgated the Subtitle D criteria (40 CFR Part 257) in 1979. These rules were corrected and amended in the Federal Register twice in 1979 and again in 1981. The federal criteria set standards in eight areas: floodplains, endangered species, surface water, ground water, land used for production of food chain crops, disease, air, and safety. The level of detail varies significantly among these eight areas of concern.

Floodplains

EPA rules prohibit siting municipal landfills in floodplain areas where the landfill would restrict the flow of a 100-year flood. (Such a flood has a magnitude that occurs only once every 100 years.) Landfills should not reduce the temporary storage capacity of a floodplain or result in a washout of solid waste that presents a hazard to humans, wildlife, or land and water resources.

Endangered Species

Neither facilities nor practices can cause or contribute to the harassment, wounding, capture, trapping, or killing of endangered species. Also, neither facilities nor practices can harm the habitats of endangered species.

Surface Water

Facilities must comply with Sections 404, 208, and 402 (the National Pollutant Discharge Elimination System) of the Clean Water Act.

Ground Water

Facilities may not contaminate ground water beyond the solid waste boundary, unless a court or a state determines that another boundary is an acceptable compliance point and would not contaminate ground water that may be needed for human consumption.

Land Used for Production of Food Chain Crops

The rules set standards for the disposal of waste containing cadmium and polychlorinated biphenyls (PCBs) near or on land used for the production of food chain crops. The criteria set maximum pH and cadmium levels for soil and waste containing cadmium and a cadmium concentration limit for waste applied to land used for the production of certain crops. These limits apply to facilities applying solid waste within one meter of land used for producing food chain crops.

Disease

Section 257 prohibits operating a facility "unless the on-site population of disease vectors is minimized through the periodic application of cover material or other techniques as appropriate so as to protect public health" (Section 257.3-6). The same section sets standards for facilities that dispose of sewage sludge and pump septic tanks.

Air

The criteria prohibit violation of requirements developed under Clean Air Act State Implementation Plans and, with few exceptions, open burning.

Safety

The safety requirements address four potential problem areas: explosive gases, fires, bird hazards to aircraft, and public access. The Agency rules set a cap at 25 percent of the lower explosive limit of gas in facility structures and a cap at the lower explosive limit at facility boundaries. In addition, no facility or practice may pose a fire hazard. Section 257.3-8 prohibits siting facilities within 10,000 feet of airports serving turboprop aircraft or within 5,000 feet of airports serving piston-only aircraft. Finally, the criteria prohibit uncontrolled public access to landfills, which may cause a health hazard.

HSWA

Section 4010 of HSWA requires EPA to prepare a report for Congress by November 8, 1987, indicating whether the current criteria are adequate to protect health and the environment from ground-water contamination and recommending whether additional enforcement authorities are needed. Section 4010 of HSWA also requires EPA to revise the current criteria by March 31, 1988, for facilities that may receive hazardous household waste or small-quantity generator waste.

Section 4005 of HSWA requires each state, not more than 18 months after the promulgation of revised criteria, to "adopt and implement a permit system or other program of prior approval and conditions" to ensure that units receiving household hazardous waste or small-quantity generator waste comply with the revised criteria. Each state's program is to be approved by the Administrator.

State Requirements

State regulatory requirements can be divided into seven areas: permitting and administrative requirements, design criteria, operation and maintenance standards, location standards and restrictions, monitoring requirements, closure and post-closure care requirements, and financial responsibility. Data on these requirements were collected through an EPA review of state Subtitle D requirements.¹ EPA's findings are summarized below for each of the seven areas.

¹U.S. Environmental Protection Agency, Office of Solid Waste, Draft Final Report on Solid Waste Disposal in the United States, Report to Congress, Vol. 2 (April 15, 1988), Chapter 5 and Appendix D, Tables D-1 through D-6.

Permitting and Administrative Requirements

All but one of the states and territories require the issuance of a license or permit before MSWLFs can operate, although only 51 percent of such units actually are permitted. The majority of permit requirements relate to soil conditions, ground-water information, and surface water information. Less than a third of the states and territories have requirements concerning total acreage, the life of the facility, and future use of the property.

Design Criteria

Most states and territories (50) have standards that require the owner/operator to control the generation, storage, collection, transportation, processing and reuse, and disposal of waste in a safe, sanitary, esthetically acceptable, and environmentally sound manner. Information needed to evaluate MSWLF design and operating conditions according to these criteria is generally required on the permit application.

Leachate management is mandated by 27 states and territories, although design specifications vary widely. Twenty-four states have promulgated liner design specifications.

Of the 55 governments studied, 31 require a system for the control of decomposition gas. Many use the lower explosive limit requirements derived from the federal criteria. Others require a venting system or odor regulation.

Water run-on and run-off control systems are mandated by 42 states and territories. Criteria in this category require owner/operators to provide adequate drainage to minimize erosion and prevent ponding.

Operation and Maintenance Standards

Operation and maintenance standards, which can be either design or performance standards, are of six types: waste management, leachate controls, gas controls, cover, safety, and miscellaneous other. Minimum operation and maintenance standards are established in 52 states and territories. Waste management

standards, although usually very general, are required by all states. Thirty-six states and territories have imposed leachate control standards.

Each state requires compliance with applicable surface- or ground-water quality standards. Twenty-two states require that explosive gas concentrations be controlled to prevent a hazard. Daily cover of sites is mandatory in most states, although sites handling only inert wastes are frequently exempted. State cover requirements often depend on the population served and amount and type of waste received. The definition of cover also varies, often being just soil or earth but sometimes including criteria such as good compactability, ability to provide an adequate seal, and ability to provide adequate protection against the infiltration of water.

With few exceptions, states require compliance with the federal safety criteria pertaining to open burning, fire control, and access limitations. Other operation and maintenance criteria include standards for drainage, litter, disease vectors (in California), dust, odors, and noise.

Location Standards and Restrictions

Forty-four states and territories have established location standards and restrictions relating to environmentally sensitive areas and setback distances. Specifically, 36 states and territories have floodplain protection standards and 39 states specify minimum distances to man-made or natural structures, such as airports, utility lines, ground waters, and surface waters. Location restrictions in critical habitat areas are specified by 16 states and territories. Only five states impose restrictions in geologically sensitive areas or in areas with particular soil conditions.

Monitoring Requirements

Thirty-eight states and territories require monitoring of ground water. Of these states and territories, 20 also require leachate monitoring. Three states and territories have leachate monitoring requirements without ground-water requirements. Ten states and territories require surface water monitoring. None of the states have air monitoring requirements.

Closure and Post-Closure Care Requirements

Almost all the states and territories have some requirements for closure and post-closure. Forty-four have both types of requirements. Seven have only closure requirements.

Financial Responsibility

Twenty of the 44 states and territories with closure and post-closure requirements require some type of financial assurance.

Summary

The implementation of landfill requirements varies greatly among states and territories. Although almost all states and territories have permit requirements, just over half of the facilities in states are actually permitted, indicating that the scope and stringency of these requirements differ. States tend to address many common concerns through their standards and requirements for design, operation and maintenance, location, monitoring, and closure. The most common standards relate to run-on/run-off control, waste management, leachate control, cover and safety controls, floodplain protection, ground-water monitoring, and closure and post-closure. Not all states, however, address each of these issues in their requirements and standards.

CHARACTERISTICS OF AFFECTED LANDFILLS

This section summarizes the key characteristics of MSWLFs: their number, size, remaining life, ownership, location, and operating practices.

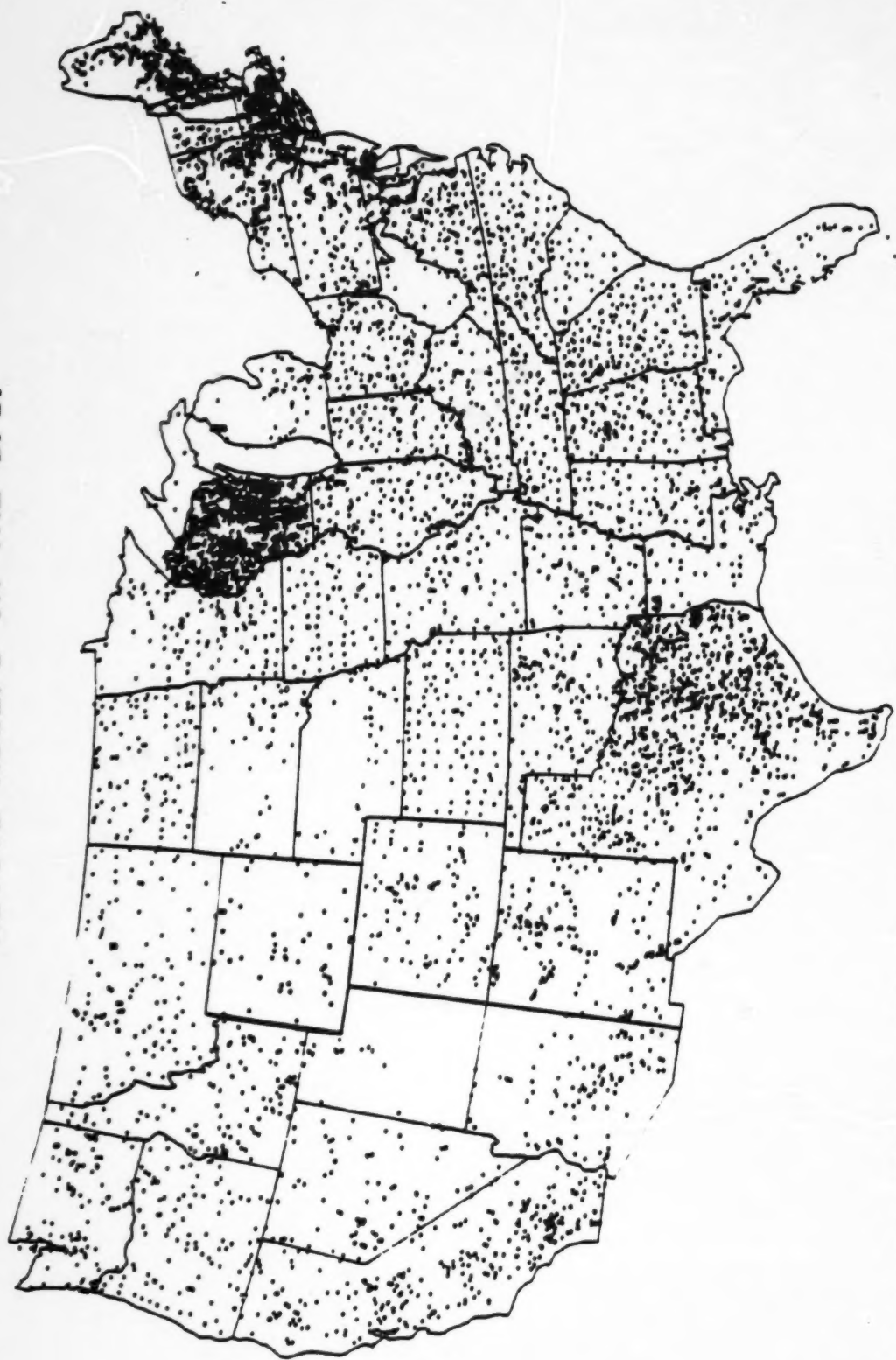
Number

EPA estimates that 6,034 municipal solid waste landfills operate in the United States and its five territories. This estimate is based on preliminary results from EPA's 1986 Solid Waste (Municipal) Landfill Survey.

Figure II-1 and Table II-1 show the distribution of MSWLFs across the country and by state. (The proportion of MSWLFs in each state in Table II-1 is drawn from EPA's earlier MSWLF state census, Census of State and Territorial Subtitle D Nonhazardous Waste Programs, which found 7,645 landfills. However, preliminary results from the more recent municipal landfill survey indicate that a more accurate estimate of the total number of landfills is 6,034. The estimates in the table are provided to indicate the distribution across states.) Figure II-1 indicates that landfill locations are most highly concentrated in a few northeastern states (including New England and parts of New York) and in Wisconsin. Wisconsin, which has only 2 percent of the nation's population, has more than 12 percent of all MSWLFs, roughly the same number as Texas and more than twice as many as California, New York, or Maine. Together, these five states--Wisconsin, Texas, California, New York, and Maine--account for approximately 37 percent of all municipal solid waste landfills.

EPA's 1986 MSWLF facility survey of 1,250 facilities provides the best recent data on the size, technical characteristics, remaining life, and ownership patterns of municipal landfills. This analysis used preliminary results for 701 active landfills that initially responded to the survey. EPA assigned statistical weighting factors to scale up the responses and estimate the characteristics of all 6,034 landfills. Thus, the data presented below show the estimated size, technical characteristics, remaining life, and ownership patterns for all municipal landfills, not just the 701 initial respondents.

Figure II-1

ACTIVE MSWLFs IN THE U.S.

Source: U.S. EPA State Landfill Census, landfill location descriptions compiled by DPRA, Inc. Into latitudes and longitudes

Note: not all landfills are plotted due to missing values, plotted locations do not match this map exactly

Table II-1
DISTRIBUTION OF LANDFILLS

State	State Census		State	State Census	
	Number	Percentage		Number	Percentage
AK	179	2.3%	NC	124	1.6
AL	122	1.6	ND	100	1.3
AR	84	1.1	NE	43	0.6
AZ	96	1.3	NH	70	0.9
CA	401	5.2	NJ	73	1.0
CO	122	1.6	NM	213	2.8
CT	91	1.2	NV	107	1.4
DE	3	0.0	NY	304	4.0
FL	126	1.6	OH	153	2.0
GA	198	2.6	OK	132	1.7
HI	20	0.3	OR	127	1.7
IA	83	1.1	PA	144	1.9
ID	95	1.2	RI	11	0.1
IL	168	2.2	SC	80	1.0
IN	98	1.3	SD	55	0.7
KS	124	1.6	TN	120	1.6
KY	107	1.4	TX	935	12.2
LA	93	1.2	UT	112	1.5
MA	203	2.7	VA	147	1.9
MD	42	0.5	VT	70	0.9
ME	294	3.8	WA	118	1.5
MI	58	0.8	WI	933	12.2
MN	105	1.4	WV	141	1.8
MO	106	1.4	WY	78	1.0
MS	108	1.4			
MT	129	1.7	Total	7,645	100.0% ^a

^aDoes not add to 100 percent because of rounding.

Source: EPA State Landfill Census.

Size

Table II-2 summarizes the estimated size distribution of municipal landfills. This table shows the number of landfills in seven size categories, measured in tons per day (TPD) of waste handled. These size categories are used later in this report to estimate the unit costs of regulatory options. As the table indicates, the largest percentage of landfills (51 percent) handle less than 17.5 TPD, 17 percent handle between 17.6 and 50 TPD, and 32 percent handle more than 51 TPD.

Table II-2
SIZE DISTRIBUTION OF MUNICIPAL LANDFILLS

<u>Model Size Waste Quantity (TPD)</u>	<u>Actual Size Range (TPD)</u>	<u>Number</u>	<u>Percentage¹</u>
10	1-17.5	3,093	51.3%
25	17.6-50	1,028	17.0
75	51-125	791	13.1
175	126-275	442	7.3
375	276-563	334	5.5
750	564-1,125	189	3.1
1,500	>1,125	157	2.6
Total		6,034	100.0%

¹Total does not add to 100 percent because of rounding.

Source: EPA Municipal Landfill Survey.

The size distribution of landfills has important implications for the economic impacts of the regulatory options. Many of the regulatory options entail requirements whose costs achieve economies of scale as the size of the unit increases. Thus, in most cases, the regulatory costs per ton of waste handled are lower for larger MSWLFs than for smaller ones.

Table II-3 shows the amount of waste handled by facilities in each size category. Whereas the number of facilities decreases in each subsequently larger size category, the amount of waste increases. For example, an estimated 157 facilities (2.6 percent of the total) are in the largest size category, yet these relatively few landfills handle 40 percent of all municipal landfill waste.

Table II-3
WASTE HANDLED BY LANDFILL
SIZE CATEGORIES

<u>Size Range (TPD)</u>	<u>Total Waste Handled (TPD)</u>	<u>Percentage of Total Waste Handled by All MSWLFs</u>
1-17.5	13,122	1.6%
17.6-50	30,610	3.8
51-125	68,763	8.6
126-275	87,002	10.9
276-563	130,455	16.3
564-1,125	149,218	18.6
>1,125	321,767	40.2
Total	800,937	100.0%

Source: EPA Municipal Landfill Survey.

Remaining Life

For the purposes of this analysis, an important characteristic of municipal landfills is the number of years they expect to remain open. Some of the regulatory options analyzed in this report impose fewer requirements on existing facilities, enabling landfill owners and operators to minimize the short-term effects of regulation by operating their existing landfills for as long as possible. Also, the remaining life of a facility affects the allocation of costs between existing and replacement facilities in our analysis. Thus, the number of years existing MSWLFs expect to remain open affects the impact of the regulatory options discussed later in this report.

Table II-4 indicates the distribution of facilities' remaining lives. Approximately 45 percent of the existing MSWLFs will close within five years. Within 15 years, almost three-quarters of all MSWLFs currently in operation expect to close. The survey data, which are based only on a sample, indicate that in a few states, including Florida, Massachusetts, New Hampshire, and New Jersey, virtually all currently active municipal landfills may be closed within 10 years.

Table II-4
REMAINING LIFE OF MSWLFs

<u>Years¹ Remaining</u>	<u>Number</u>	<u>Percentage</u>	<u>Cumulative Percentage²</u>
0	535	8.9%	8.9%
1-5	2,167	35.9	44.8
6-10	612	10.1	54.9
11-15	1,126	18.7	73.6
16-20	360	6.0	79.6
21-25	231	3.8	83.4
26-35	211	3.5	86.9
36-45	154	2.6	89.4
46-55	144	2.4	91.8
56-75	134	2.2	94.0
76-100	67	1.1	95.1
>100	293	4.9	100.0
	6,034	100.0% ²	

¹Years of remaining life equals closure year minus 1987.

²Total does not equal 100 percent because of rounding.

Source: EPA Municipal Landfill Survey.

It is not possible to use the survey data to examine past trends in total landfill capacity because the data show approximately how much capacity has been added each year, but not how much has been lost. However, recent trends in the number of new facilities opening, summarized in Table II-5, support the argument that it is becoming more difficult to site MSWLFs. In the early 1970s, roughly 300 to 400 new landfills were being built each year. During the past 10 years, however, this number has dropped to between 50 to 200 new landfills per year. Moreover, survey data indicate that landfill size has remained relatively constant resulting in a capacity shortfall.

The average size of landfills opened over the past 20 years has been between 100 to 200 TPD. Significant capacity additions are not occurring now but did occur between 1970 and 1977 because of a large number of new landfills opened during that period.

Table II-5

NUMBER OF LANDFILLS
OPENED EACH YEAR:
1970 THROUGH 1986

<u>Start Year</u>	<u>Number of Landfills</u>
1970	381
1971	201
1972	309
1973	334
1974	319
1975	396
1976	262
1977	165
1978	190
1979	144
1980	155
1981	144
1982	206
1983	129
1984	149
1985	57
1986	62

Source: EPA Municipal
Landfill Survey.

Ownership

EPA's Subtitle D landfill survey provides data on who owns landfills that accept municipal solid waste. In addition, the 1982 Census of Governments conducted by the Commerce Department contains information on the characteristics of publicly owned solid waste landfills. This information indicates which types of landfill owners will bear the initial effects of any cost increases stemming from new regulations.

Table II-6 indicates the number of landfills owned by various levels of government as well as those privately owned. The estimates reflect weighted results for 6,034 landfills from EPA's detailed facility survey. Approximately 81 percent of all MSWLFs are owned by local governments, while 15 percent are privately owned. The remainder are owned by states and the federal government. Not surprisingly, the states and the federal government own relatively few MSWLFs (many of these are landfills serving parks, campgrounds, and military bases).

Table II-6
DISTRIBUTION OF LANDFILL OWNERSHIP

<u>Operator</u>	<u>Number of Landfills Owned¹</u>	<u>Percentage of Total²</u>
Local government	4,875	80.8%
State government	82	1.4
Federal government	154	2.6
Privately owned	912	15.1
Total	6,034	100.0%

¹Total does not add to 6,034 because a few landfills did not provide ownership data.

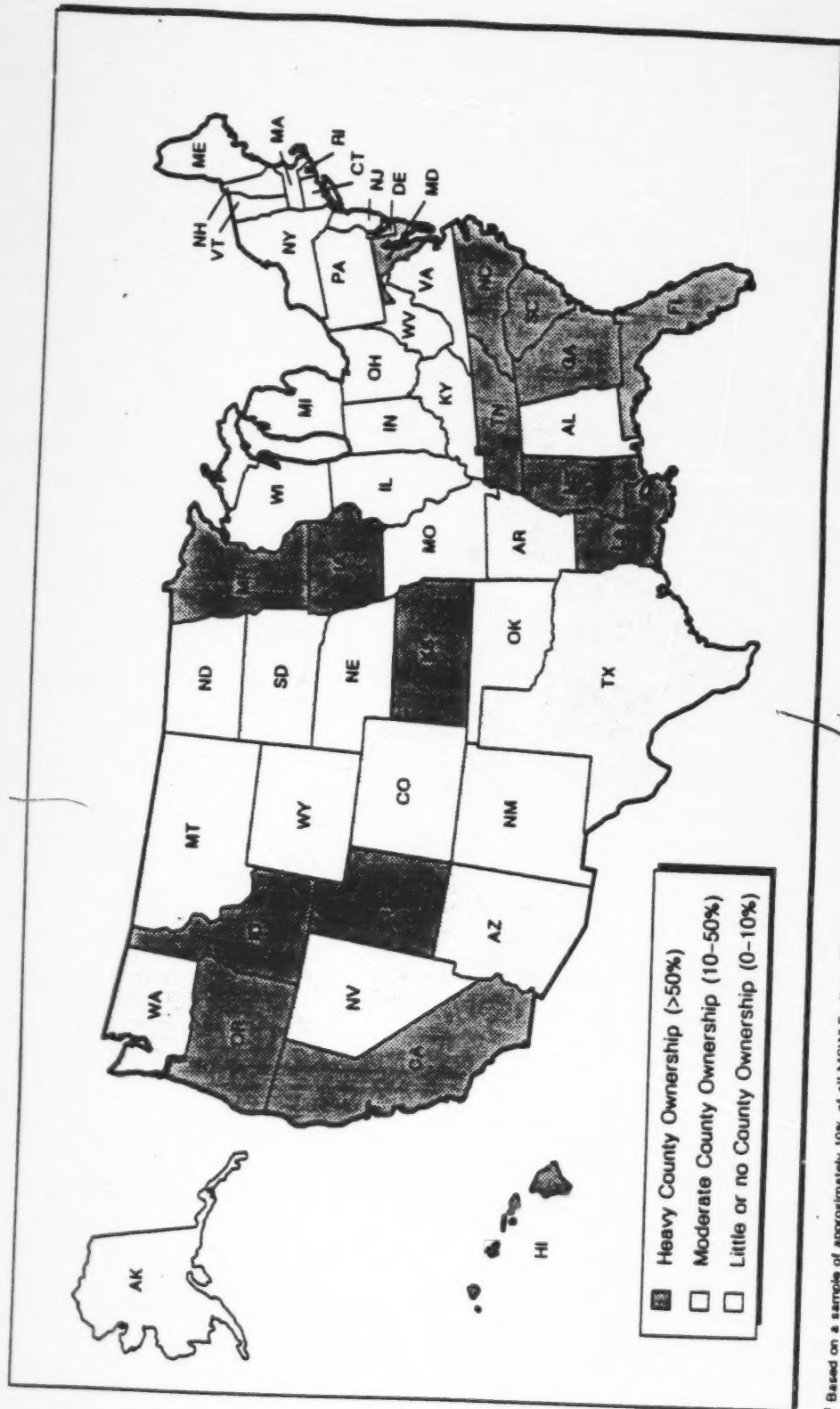
²Total does not add to 100 percent because of rounding.

Source: EPA Subtitle D Landfill Survey.

Three types of local governments own landfills: counties, cities, and towns and villages. Preliminary results from EPA's facility survey show that the approximately 4,900 landfills owned by local governments are split fairly evenly among these three types of jurisdictions, with counties owning 36 percent, cities 36 percent, and village or town governments 28 percent. The remaining landfills, about 1,100, are owned by private contractors, states, special districts, or the federal government. This even distribution of landfill ownership nationwide masks a great deal of variation in ownership patterns from state to state. Figure II-2 divides states into categories of heavy, moderate, or little or no county ownership of landfills. In New England, New York, and several states in the central part of the country, few, if any, landfills are owned by counties. In most of the southeastern states and in parts of the West, the majority of municipal landfills are owned by counties.

Table II-7 presents information from the 1982 Census of Governments on landfill ownership by local governments. The data examine landfill ownership from a slightly different perspective, focusing on how many local governments actually own landfills. The data are older than those compiled by EPA, and cover only

Figure II-2
Estimated County Landfill Ownership¹



¹ Based on a sample of approximately 10% of all MSWLFs (i.e., 701 responses to EPA's MSWLF survey).
Source: U.S. EPA Municipal Landfill Survey.

Table II-7

LANDFILL OWNERSHIP WITHIN LOCAL GOVERNMENTS

County Government

<u>Population</u>	<u>Number of Governments</u>	<u>Number with Landfills</u>	<u>Percentage</u>
500,000+	68	35	51.5%
250,000-500,000	88	36	40.9
100,000-250,000	218	89	40.8
50,000-100,000	374	195	52.1
25,000-50,000	611	291	47.6
10,000-25,000	957	453	47.3
Less than 10,000	725	299	41.2
Total	3,041	1,398	Avg. 45.9%

Municipal Government

300,000+	49	24	49.0%
200,000-300,000	23	15	65.2
100,000-200,000	97	45	46.4
50,000-100,000	250	70	28.0
25,000-50,000	525	152	29.0
10,000-25,000	1,253	331	26.4
5,000-10,000	1,515	385	25.4
2,500-5,000	2,078	449	21.6
Total	5,790	1,471	Avg. 36.4%

Township Government

100,000+	30	8	26.7%
50,000-100,000	73	14	19.2
25,000-50,000	214	39	18.2
10,000-25,000	702	182	25.9
5,000-10,000	962	217	22.6
2,500-5,000	1,724	323	18.7
Total	3,705	783	Avg. 21.9%

Source: 1982 Census of Governments.

jurisdictions with more than 2,500 people. The data indicate that, nationwide, roughly equal numbers of landfills are owned by counties, cities, and townships. Larger cities and towns are more likely to own landfills than their smaller counterparts, but the same conclusion does not hold true for counties, where the size of the county's population seems to have little effect on whether or not the county owns a landfill.

The type of ownership is correlated with other important landfill characteristics such as size and operating life. Landfills operated by towns and villages are more likely to be small (over 84 percent handle less than 17.5 TPD) and are also somewhat more likely to stay in operation for more than 30 years. County and city landfills are more likely to be moderately sized (i.e., handle between 10 and 275 TPD). Eighty-nine percent of all county landfills and 91 percent of all city landfills fall into this size category. Privately owned landfills are the most likely to be large (31 percent of all private landfills handle more than 275 TPD); however, approximately 37 percent of all private landfills handle less than 17.5 TPD. Private landfills are also somewhat more likely than publicly owned landfills to operate for fewer than 20 years.

Location of Existing MSWLFs

The discussion of location focuses on areas containing landfills that may be restricted or banned under the proposed rule. EPA is considering adding location restrictions for four location categories: active seismic zones (areas within 60 meters of an active fault), unstable areas (e.g., Karst zones, landslide-susceptible areas), fault areas, and wetlands. Existing landfills operating in some of these zones may be required to cease operations. If these requirements are imposed, variances may be granted on a case-by-case basis if no practicable alternative is available. The following discussion also covers some of the technical characteristics of MSWLFs, such as the proximity of existing landfills to drinking water supplies, and subsurface soil type.

Several different sources of data were used to assess the location of existing MSWLFs. Information on which jurisdictions contain active seismic faults was obtained from Subtitle C (40 CFR Part 264, Appendix VI). Information on the number of MSWLFs located in floodplains, wetlands, and Karst areas, as well as data on soil type and proximity to drinking water supplies, was obtained from preliminary results from the MSWLF facility survey. Note that some inaccuracies in these characterizations may result because they are based on extrapolations from a limited survey sample.

Banned/Restricted Areas

Nationwide, approximately 35 percent of all existing MSWLFs are located in counties that contain seismic faults that have been active within the Holocene period. However, we have no way of knowing how close landfills located in these counties are to the active faults. Four of the five states bordering the Pacific Ocean (Alaska, California, Hawaii, and Washington) have a majority of their MSWLFs located in counties with active fault zones. The six New England states and New York also have a majority of their landfills in this category, as do South Carolina and Tennessee. Many of the states bordering the Rocky Mountains, the Sierra Nevadas, and the Mississippi River have at least 25 percent of their landfills in counties where there has been recent seismic activity. However, the two states with the largest number of MSWLFs, Wisconsin and Texas, have no landfills near active fault zones.

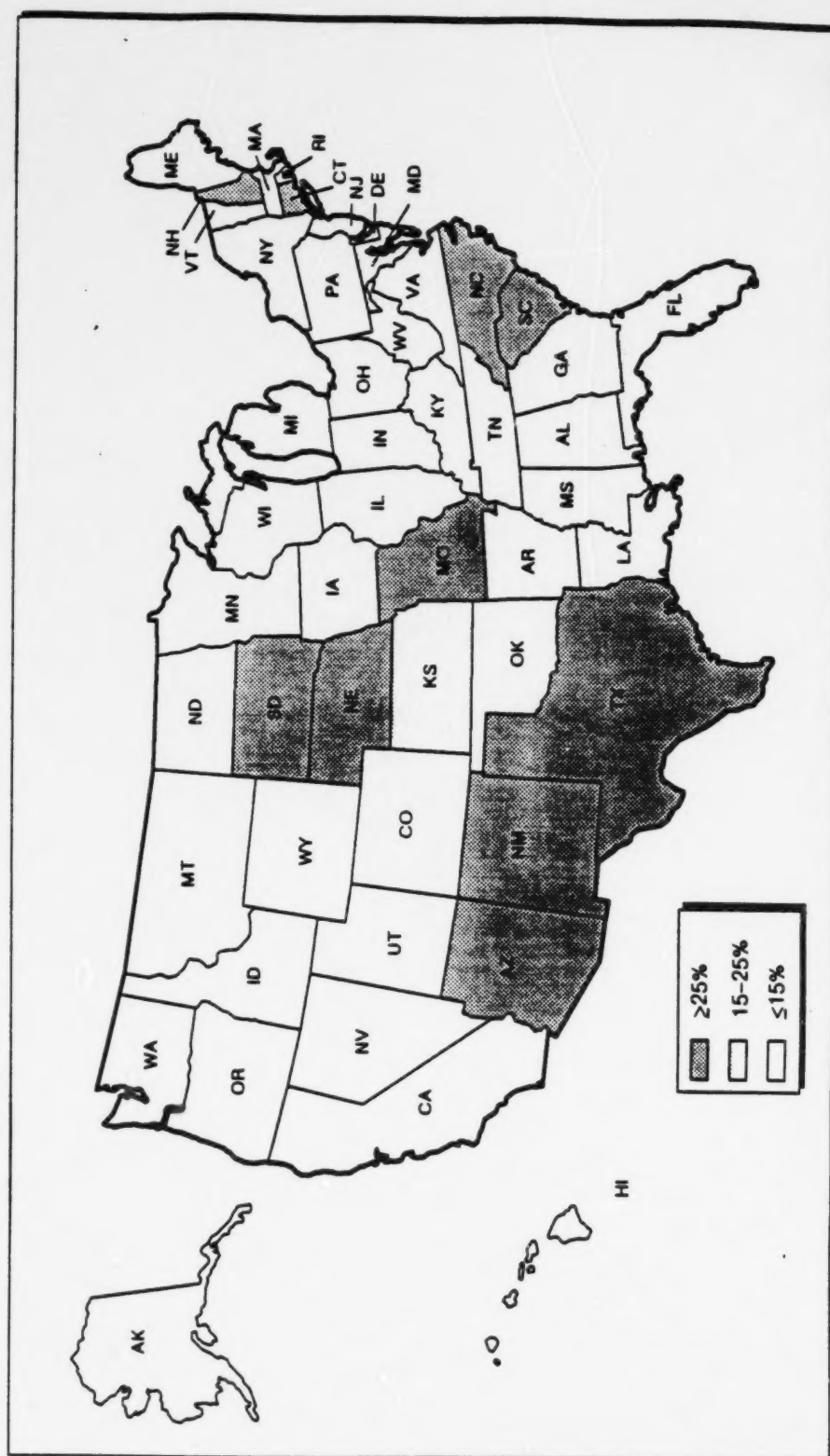
Approximately 13 percent of all MSWLFs are located, at least in part, within the 100-year floodplain (see Figure II-3). A smaller percentage of MSWLFs, 6 percent, are located in areas classified as wetlands, such as swamps, marshes, and bogs (see Figure II-4). Certain areas of the country are classified as Karst terrain, a type of topography characterized by sinkholes, caverns, and other formations caused by the action of surface and ground water in soluble rock such as limestone. An estimated 4 percent of all MSWLFs are located in Karst terrain (see Figure II-5).

Landfills located in sensitive areas such as the ones described above are a concern because the location may cause the failure of containment mechanisms for contamination (e.g., earthquakes or floods may destroy liners or covers designed to minimize contaminant migration) or because contamination may be particularly difficult to clean up in wetlands or Karst terrain.

Proximity to Drinking Water Supplies

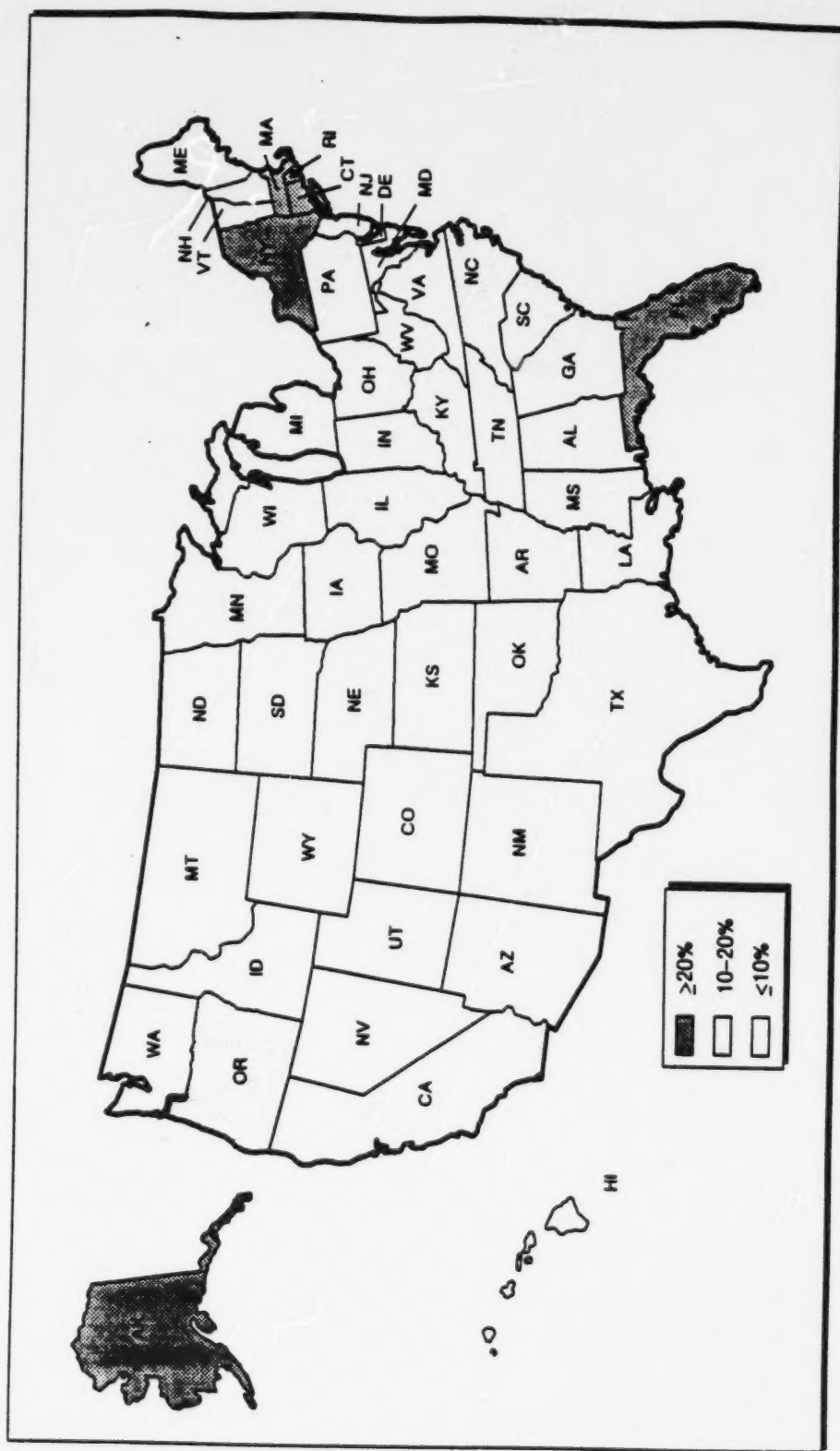
Another location characteristic that increases the potential for human exposure to contamination is proximity to downgradient wells, streams, or reservoirs that are used for drinking water supplies. Preliminary results from the MSWLF survey indicate that an estimated 46 percent of all MSWLFs nationwide are located within one mile of a public or private well that provides drinking water, and approximately 6 percent are located within the same distance of a river or stream that serves as a drinking water supply.

Figure II-3

Estimated Percentage of Landfills Located in Floodplains¹

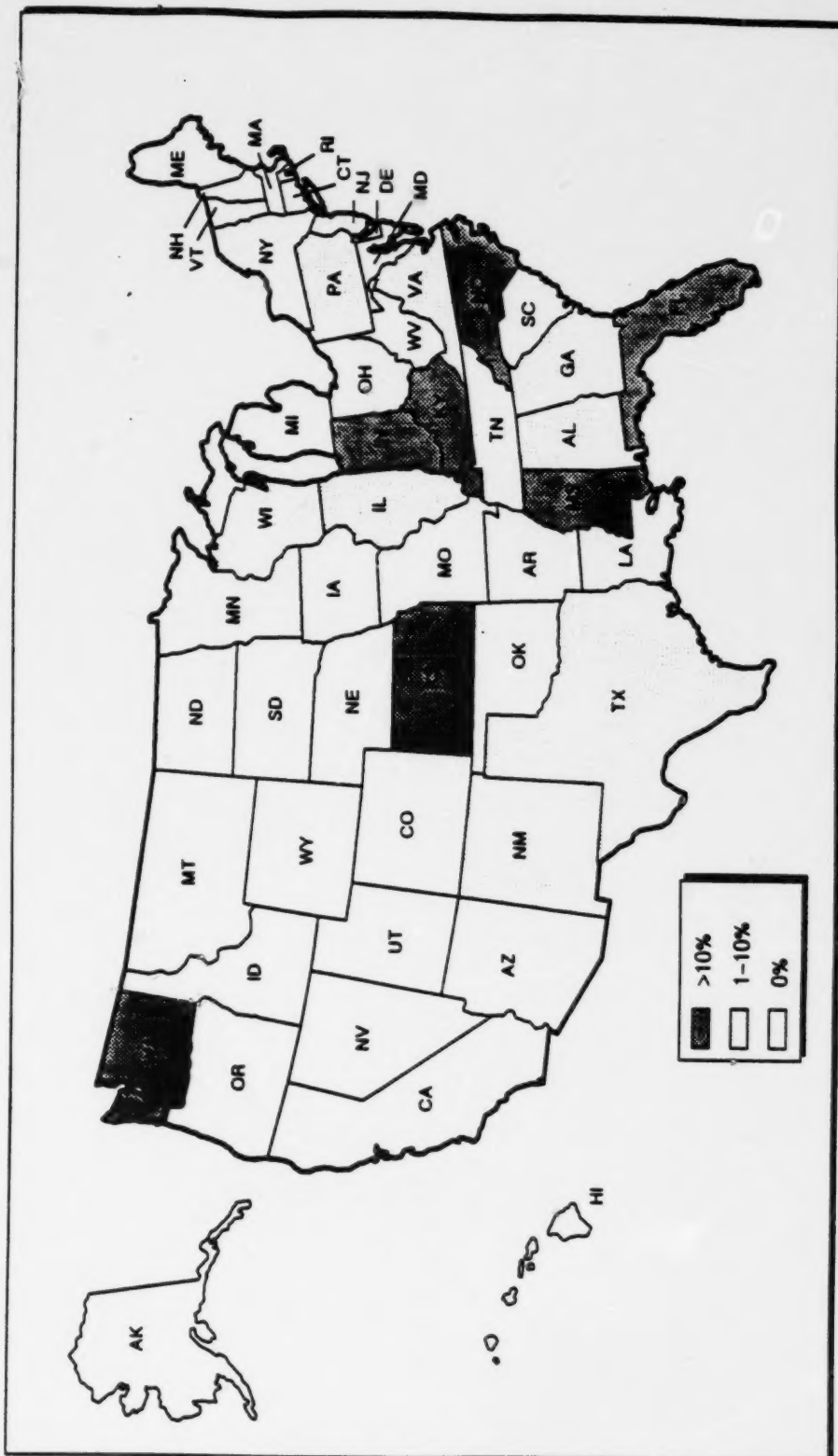
¹ Based on a sample of approximately 10% of all MSWLFs (i.e., 701 responses to EPA's MSWLF survey).
Source: U.S. EPA Municipal Landfill Survey.

Figure II-4



Based on a sample of approximately 10% of all MSWLFs (i.e., 701 responses to EPA's MSWLF survey).
Source: U.S. EPA Municipal Landfill Survey.

Figure 11-5



¹ Based on a sample of approximately 10% of all MSWLFs (i.e., 701 responses to EPA's MSWLF survey). Source: U.S. EPA Municipal Landfill Survey.

Environmental Setting

Hydrogeologic characteristics of landfill location play a major role in determining whether any leachate generated at a site eventually reaches the ground water. One characteristic that affects contaminant migration and health risk is the thickness of the unsaturated zone that separates the bottom of the landfill from the aquifer (see Chapter V). At approximately half of all MSWLFs, the average reported distance from the bottom of the landfilled wastes to the seasonal high water table is 20 feet or less. At 11 percent of the MSWLFs, there is no separation between landfilled wastes and the seasonal high-water table.

Another factor that influences the rate of contaminant migration is the type of soil in the unsaturated zone. The least permeable type of soil is clay. According to the data compiled through EPA's MSWLF survey, the predominant subsurface soil types for approximately 58 percent of all MSWLFs are either clay or sandy clay.

Operating Practices of MSWLFs

Information on the operating practices of MSWLFs was obtained from the MSWLF survey. This section summarizes the types of wastes handled by MSWLFs; it also describes the monitoring practices of existing facilities.

Most MSWLFs accept primarily household waste. At 76 percent of all MSWLFs, over half of the waste received comes from households. MSWLFs accept waste from a variety of other sources, however, including commercial establishments (offices, restaurants, and retail stores), very small quantity generators (VSQGs) of hazardous wastes, and producers of other industrial waste, construction/demolition wastes, and sewage sludge. Of these other types of waste, by far the most common types accepted are commercial waste and construction/demolition waste. For the majority of facilities, commercial waste represents at least 15 percent of their waste stream and construction/demolition waste at least 5 percent. Table II-8 shows the percentage of facilities handling each waste type and the percentage whose waste flow consists primarily (more than half) of each waste type.

Table II-8
LANDFILLS HANDLING EACH WASTE TYPE

Waste Type	Percentage Handling	
	Receive at All ¹	Accounts for More than 50 Percent
Household	100%	76%
Very small quantity generator	21	0
Commercial	91	4
Industrial	47	0
Demolition/construction	80	0
Sludge	35	0

¹Percentage is calculated only for those landfills that responded to the question. For example, only 47 percent answered the question about sludge and 35 percent of those (16 percent of all surveyed landfills) accepted sludge.

Source: EPA Municipal Landfill Survey.

Many landfills did not estimate the amount of VSQG or industrial waste they handle. Of the approximately 30 percent of the facilities that indicated whether or not they handled VSQG waste, most facilities reported handling no VSQG waste. For those facilities that did report handling VSQG waste, it rarely exceeded more than 1 percent of the total waste handled. Slightly more than half of the facilities provided information on whether or not industrial waste was accepted. Approximately 40 percent of those responding indicated that they handle some industrial waste, and at a few of these facilities industrial waste represents as much as 20 percent of the total waste handled.

Environmental Monitoring

Table II-9 indicates the percentage of MSWLFs that report ground-water, surface water, air, or gas monitoring. Approximately 38 percent of all facilities monitor ground water; less than half this number monitor surface water; and fewer than 10 percent monitor air emissions or levels of methane gas. Forty-eight percent of the facilities that monitor ground water have one to three upgradient wells and five or fewer downgradient wells, and analyze samples from these wells four times per year.

Table II-9	
MONITORING PERFORMED BY MSWLFs	
<u>Type of Monitoring</u>	<u>Percentage</u>
Ground water	38.2%
Surface	15.1
Gas	6.4
Air	2.1
Source: EPA Municipal Land-fill Survey.	

Facility Design

A final characteristic of MSWLFs is the method used for landfilling the waste. Approximately 65 percent of all MSWLFs use a cut-and-fill (or trench) method, which entails excavating an area in which to place the waste and then covering the waste with the material obtained during excavation. The remaining landfills rely on the area-fill method, in which waste is spread uniformly over the surface of the ground and then covered with soil. About 15 percent of the landfills that use the cut-and-fill method in some sections rely on the area-fill method in other parts of the facility. The area-fill method is often used when the landfill site contains a natural depression or slope.

III. REGULATORY OPTIONS

This chapter describes the four regulatory options analyzed in this RIA for complying with the mandate of HSWA: the proposed approach and three alternatives.

The Proposal is based on performance standards for new and existing units. The Proposal describes those performance standards but, since there is no single method for designing facilities to meet these standards, it provides guidance for owners and operators on how to design and operate MSWLFs to meet the standards. The performance standard for new units is linked to a design goal, a health- and environmental-based ground-water risk level. States choose the design goal within a prescribed risk range of 10^{-4} to 10^{-7} , and facility owners must then determine what design will be necessary to meet the goal. We analyzed the effect of meeting this design goal at two possible points of compliance (POCs), at the waste management unit boundary and at a more distant, alternative compliance point. The performance standard for existing units is to prevent infiltration of water into the cover and into the waste after closure. This will require the use of an appropriate final cover on the unit.

In this chapter we describe how we simulated the response of owners and operators to these performance standards and to the other proposed requirements. The emphasis of the analysis is on the design and operating requirements that have the largest effect on cost and benefit estimates.

In addition to the Proposal, we analyzed three regulatory alternatives. These were designed to illustrate how alternative specifications of the revised criteria would affect the estimates of cost, economic impact, risk, and resource damage. Alternatives 1 and 3 impose uniform requirements on all MSWLFs, but Alternative 1 imposes more stringent design requirements. Instead of basing designs on a performance standard, Alternative 2 assigns designs to units based on their location (i.e., the hydrogeologic conditions and climate at the site).

PROPOSAL

EPA has developed its proposed rule around performance standards for MSWLFs. These standards set the objectives for owners and operators in determining how to design and operate new

and existing facilities. The rule provides guidance for how facilities can meet these standards, but no specific design requirements are included. The Proposal also includes a set of general facility standards and corrective action requirements to address releases; all MSWLFs must comply with these provisions.

In the RIA, even though we often refer to the Proposal as a single option, we have modeled the Proposal at one design goal and two possible compliance points that states could establish under the rule. We have modeled the effects of the Proposal at a 10^{-5} design goal chosen from the allowable range of 10^{-4} to 10^{-7} . The Proposal also allows for flexibility in determining the POC for new units to meet the design goal. As a more stringent alternative, the Proposal describes the POC at the waste management unit boundary, modeled as a point 10 meters from the unit. States may establish an alternative boundary as the compliance point; the Proposal requires that this alternative POC be no more than 150 meters from the waste unit boundary and must be on land owned by the facility owner. For modeling purposes, therefore, we have simulated the cost and effectiveness of the Proposal assuming first that new MSWLFs comply with a 10^{-5} design goal at the waste management unit boundary (Proposal with 10-meter POC) and then assuming compliance at an alternative POC 150 meters from the unit (Proposal with 150-meter POC). Actual effects of the Proposal will vary from those estimated depending on the state-selected design goal and POC.

Since the Proposal does not detail the designs required to meet the performance standards, we were obliged to simulate the response of owners and operators to the Proposal and alternatives. In the next sections we summarize the rationale behind the different compliance scenarios we have selected to meet the performance standards and then describe how we assigned landfills to the scenarios.

Compliance Scenarios

To estimate the costs and effectiveness of the Proposal, we developed a modeling approach that would allow us to simulate how the performance standards in the rule would affect the 6,034 MSWLFs and how the landfills could adjust their design and operations to comply with the revised criteria. Because the design goal cited in the performance standard is based on risk, we relied on the Subtitle D Risk Model (described in Chapter IV) to estimate the effect of the performance standard on MSWLFs. The model predicts human health risk from a number of hypothetical drinking water wells downgradient from the landfills. We used these results to identify the settings in which landfills would already comply with the design goal given their current design and operation.

III-3

The model results under baseline conditions (i.e., current designs) indicated that 61 percent of the MSWLFs would have 300-year average risks below 10^{-5} if the point of compliance is at the waste management unit boundary. If the Proposal with the 10-meter POC is used, therefore, over half of the MSWLFs would not need additional design features to meet the design goal. If all the landfills are governed by a state alternative POC at 150 meters from the unit, the fraction meeting the design goal would rise to 79 percent. As expected, the more distant compliance point allows for additional dilution and attenuation of constituents so the potential risks at that POC are generally lower. If the design goal were set at a different level (e.g., 10^{-6}), the fraction meeting the goal would change.

MSWLFs that would not comply with the proposed design goal at the appropriate POC must be designed with liners, leachate collection systems (LCS), and final cover systems as needed to meet the goal. The specific design needed will vary depending on the location of the landfill. New units may need some or all of these components to meet the goal and the designs that we modeled are described below.

Existing units are subject to a different performance standard (prevent infiltration) and changing the cover design is the approach contemplated in the Proposal. Retrofitting liners and LCSs onto existing units was rejected by the Agency as being impractical, possibly environmentally hazardous, and disruptive of ongoing solid waste management activity.

Requirements Under the Proposed Rule

The proposed rule does not explicitly define the design requirements, but the rule does indicate the design components that EPA believes will have the greatest effect on meeting the performance standard. To simulate compliance with the design goal, we assigned units to one of three designs: the baseline design, which assumes an unlined landfill with a cover consisting of earth and vegetation; an unlined design with a synthetic cover system; and a landfill with a synthetic cover system, a synthetic liner, and an LCS. These three designs were assigned to landfills for modeling purposes only; facilities could use other designs to comply with the performance standard. We describe the modeling assumptions in Chapter IV.

The Proposal includes other provisions that have an impact on costs and effectiveness, but are not dependent on the performance standard. The requirements for new and existing units include:

III-4

- Developing procedures for excluding hazardous waste from the landfill,
- Monitoring for explosive gases in the subsurface and in structures,
- Adding run-on and run-off controls,
- Preparing a closure plan,
- Providing for two-phased post-closure care,
- Demonstrating financial responsibility for closure, post-closure, and known releases,
- Monitoring for ground-water contamination; establishing trigger levels and a ground-water protection standard (GWPS); and performing corrective action when required, and
- Restricting the siting and operation of MSWLFs in some settings.

Some of these provisions require only additional labor, while others require capital investment as well. Further descriptions of how each of these provisions is analyzed are contained in Chapter IV.

ALTERNATIVE 1

This option is more stringent than the Proposal. First, it specifies that all units must comply with a uniform set of design requirements; meeting the performance standard, for example, will not excuse a landfill from cover and containment system requirements. General facility standard requirements similar to those in the Proposal are also imposed on landfills under this option. These include extended post-closure care, corrective action where required, gas monitoring, run-on and run-off controls, ground-water monitoring, a plan for excluding hazardous waste, and a closure plan.

This Alternative assumes that a backup cover system is always necessary to ensure that leachate generation is minimized. To this end, the Alternative calls for installation of a composite cover system at closure. The system consists of a synthetic layer plus a layer of recompacted clay. Both new and existing units must use this cover system.

New units must all include a redundant containment system, similar to that specified for hazardous waste landfills under Subtitle C of RCRA. The system includes two synthetic layers, with leachate collection systems above each synthetic, and a supporting clay layer to delay leachate migration if leachate escapes the two synthetic layers. As with the cover system, this containment system is more stringent than any system modeled under the Proposal.

Finally, the ground-water monitoring sampling and testing procedures for new and existing units are similar to those specified for the Phase I monitoring under the Proposal. The detection monitoring program described in 40 CFR 264 is used, however, instead of the Phase I scheme in the Proposal.

ALTERNATIVE 2

Alternative 2 represents a categorical approach for determining the necessary cover and containment system designs. The categories are based on location characteristics that, in turn, define a set of design requirements. The emphasis of this Alternative is on meeting engineering requirements instead of risk-based requirements.

The underlying principles for this Alternative are that the design must prevent liquids from reaching the aquifer during the facility's active life and the final cover must minimize the infiltration of liquid into the waste. The designs we selected to meet these standards include various combinations of containment systems, leachate collection systems, and final cover systems. The assignment of landfills to specific designs is described in Chapter IV.

In addition to these location-based design standards, this Alternative includes the same general facility standards described above for the Proposal. These include extended post-closure care, ground-water monitoring, and corrective action as required.

ALTERNATIVE 3

Alternative 3 imposes on MSWLFs only ground-water monitoring, corrective action as necessary, and extended post-closure care. No additional design components such as covers or liners are added, and no general facility standards are included (e.g., location standards and run-on and run-off controls). Both new and existing units are required to meet these standards at the unit boundary. Compared to the other regulatory options, this Alternative is the most similar to the statutory minimum (i.e., ground-water monitoring, location standards, corrective action as necessary) mandated under HSWA.

The modeling assumptions for all the regulatory options are discussed in detail in Chapter IV.

IV. METHODOLOGY

This chapter describes the methodology we used to simulate the cost, economic impact, and effectiveness (risk reduction and resource damage reduction) of the proposed criteria revisions and the three alternative approaches.

COST ANALYSIS

This section describes the cost analysis, which estimates the incremental costs of the regulatory options with a baseline of current practices.

The next section describes the cost model in more detail, focusing first on the physical design aspects and then on the cost estimates. Then we describe model inputs to demonstrate how the model simulates the effect of the various options analyzed. Finally, we discuss adjustments to the model's cost results so that we can express the costs of different options in a consistent way (e.g., incremental costs per ton of waste) and so that the results are consistent with the needs of the economic impact analysis and the cost-effectiveness analysis.

The third section describes the application of the model to the various regulatory options presented in Chapter III, covering the baseline specifications and the specifications for the proposed rule and the three regulatory alternatives.

The final section describes how we scaled the model results up to national cost estimates. Results of the cost analysis are presented in Chapter V.

To develop a methodology for the cost analysis, we considered the need to estimate incremental costs and the need to integrate the cost analysis with the benefits analysis, which simulates the performance of new landfills under baseline conditions and under each regulatory option. The basis of the cost analysis is a facility design and cost model, developed by Pope-Reid Associates, that takes selected user-supplied variables (such as tons per day and any of hundreds of design specifications) and produces the specifications and costs for a landfill.

This design and cost model first identifies (or allows the user to specify) the various steps involved in designing, constructing, operating, and closing a landfill; combines this information with data on costs and fees for the components; and estimates the total cost of the landfill. The cost components include a wide range of items, such as land, clearing, excavation, equipment, labor, liner materials, and environmental monitoring devices.

Design and Cost Model

Facility Design

The model's initial routine calculates the physical dimensions and parameters of the landfill. The model includes several basic assumptions (e.g., the landfill unit is square) but allows the user to specify a range of variables, including:

- Waste characteristics: quantity, density, and operating life;
- Unit dimensions: depth of excavation, below-grade slopes, cover slopes, and height above grade;
- Containment and cover designs: drainage systems, cover materials and thicknesses (up to ten layers), containment system materials and thicknesses (up to ten layers), leachate collection and treatment systems, and gas migration controls; and
- Monitoring options: gas monitoring probes, continuous gas monitors, ground-water monitoring, surface-water monitoring.

The model then calculates the materials and activities required to support these options, including:

- Labor inputs: hours needed to design, construct, and operate systems at the facility;
- Materials costs: costs for land, heavy machinery and equipment, roads, fencing, buildings, fill material, liner and cover material; and
- Indirect costs: engineering, testing, quality assurance (QA), contingency, and contractors' fees on materials and installation.

Within a model run, the model specifies the components required to construct and operate a landfill and the costs associated with each. The physical design parameters are also used as inputs to the Failure/Release Submodel of the Subtitle D Risk Model, described later in this chapter.

Facility Costs

The model summarizes the estimated facility costs for each design simulated, measuring costs for direct capital, indirect capital, operation and maintenance, closure, and post-closure. Corrective action costs may apply to some facilities, but these are estimated by the Risk Model (since the need for corrective action is simulated by the Risk Model) and are added separately. The corrective action cost methodology is described later in this chapter.

Direct Capital. Capital costs dominate the other cost categories and include the large initial costs, such as equipment purchase, land purchase, excavation, site preparation, design, and any environmental monitoring or containment systems. Capital costs also occur intermittently throughout the operating life of the landfill when "packages" of equipment used to operate the landfill are purchased. The pieces of equipment used depend on the size of the landfill. The model specifies 13 different equipment packages, depending on unit size. At small landfills, the appropriate package includes multipurpose machines like bulldozers that can serve several functions, including clearing, moving waste around the site, and compacting waste. Larger landfills can afford more specialized, efficient equipment at a lower cost per ton of waste managed. Capital costs for covering the landfill occur at closure and are discussed below.

Indirect Capital. Indirect capital costs, which constitute a substantial fraction of the total cost of capital, consist of:

- Contractor's fee: profit for construction contractor;
- Construction and field expenses: cost of temporary construction and other overhead;
- Spare parts: cost of equipment and parts for maintenance;
- Contingency: costs for unpredicted events and design changes;

- **Inspection and testing:** cost for a testing company to ensure that design specifications are met; and
- **Quality assurance:** additional fee to cover added cost of inspecting, testing, and documenting that design specifications for containment and cover systems have been met.

The percentages, used for each of these costs is set by the user.

Operation and Maintenance. The dominant component of annual operation and maintenance (O&M) is labor costs. The model determines the need for labor hours on the basis of the quantity of waste handled; the different categories of labor hours required are linked to the equipment costs described above under direct capital. Other annual cost components include equipment maintenance and fuel, fees for licenses or permits, environmental monitoring costs (if any), and costs for leachate management (if applicable). For this analysis, all collected leachate is assumed to be trucked off site to a publicly owned treatment work (POTW). Although other options are available, this is the most common method of leachate management according to preliminary results from the MSWLF facility survey.

Closure. The dominant cost at closure is for the final cover applied to the landfill. The model includes the direct and indirect capital cost components for the cover, its design, the appropriate drainage system, and final vegetation for the site.

Post-Closure. All the regulatory options call for post-closure care after the unit no longer accepts waste. The costs of this care include applicable environmental monitoring, leachate treatment, cover and slope maintenance, and annual inspections.

Generic Inputs to the Model

We used the model to analyze a range of options but, in the interest of simplicity, constrained the number of possible user inputs to focus on design parameters affected by the proposed rule and the alternatives. The specifications affected by each option are discussed later in this chapter. Many other physical design parameters were set independently of the requirements so they do not vary over the different options. These parameters are described below.

Sizes. We selected seven model sizes of landfills to represent the range of sizes observed in the population. The size categories are defined in tons per day of waste. Each landfill is assumed to operate for 260 days per year. Table II-2 lists the size categories and their relative frequency in the surveyed

population (see Chapter II for a more detailed discussion). Size is the primary determinant of overall cost; we show later, however, that landfills exhibit increasing returns to scale: the larger the landfill, the lower the cost per ton of waste managed.

Design Inputs. The landfills are assumed to operate in one phase. All the excavation is done initially and the final cover is placed over the waste at the end of the operating life. The side slopes of the excavation are set at 1:1, and the unit depth is held constant at 15 feet; this is consistent with the Risk Model.

Operating Procedures. All the landfills are assumed to use a cut-and-fill method of operation: the operator excavates a trench and places waste both below grade (in the trench) and above grade in a mound. All new landfills are assumed to operate for 20 years; existing landfills have remaining lives as reported in the survey.

Adjustments to the Engineering Cost Estimates

The model's unadjusted output presents the sum of all costs (in current, 1986 dollars) for each year of operation and, if applicable, throughout the post-closure period. To apply the results to the economic analysis and take account of the time value of money, the model discounts the costs using a 3 percent real discount rate to provide the present value of the stream of costs.

Because the emphasis of our analysis is on incremental costs, we used the cost model to generate estimates for a base-line, unregulated landfill and subtracted those costs from the costs for regulated units (the model specifications are described below). The difference equals the incremental cost attributable to the regulations.

As described in the previous chapter, several of the regulatory options have different requirements for new and existing landfills. This difference has implications for adjustments to the cost model results, and the approach we have taken is described next.

New MSWLFs. All requirements that affect new units are assumed to apply from the time construction begins. The incremental cost presented is the difference between replacing the unit with a new, regulated unit and a new, unregulated unit, taking into account the time at which construction begins. We have assumed that each MSWLF identified in the survey will be

replaced at the end of its active life with a new MSWLF that conforms to the appropriate requirements.¹

This assumption provides a reasonable upper-bound estimate of the regulatory costs because it does not allow for lower-cost compliance approaches, such as regionalization, recycling, or use of resource recovery facilities. Ideally, the analysis would incorporate these other waste management options that could be chosen once the remaining life of an existing MSWLF is exhausted. These other options, however, involve site-specific, local decisions that are difficult to predict on a national scale and are beyond the scope of this analysis.

In analyzing the incremental costs per year, we assume that the operator will recover the costs over the entire active life of the unit. Given our assumptions, the present value of the incremental cost estimated by the model for 20 years of operation and for the post-closure care period is annualized over the 20-year operating period. A 20-year operating period was selected to be somewhat conservative and yet consistent with the operating lives reported in the landfill survey. Approximately one-third of these MSWLFs have operating lives of 20 years or less. For landfills with longer lives, annualized costs will be lower owing to the increased amortization period for capital costs. The 20-year annualized cost estimate is used in measuring cost-effectiveness (e.g., cost per case avoided for new units) and in combination with costs for existing facilities in the economic impact analysis, which is described below in detail.

Existing MSWLFs. The approach for estimating costs for existing units is more complicated. As we described for new units, a landfill owner is likely to estimate all the costs that will be incurred over the lifetime of the unit and the revenue required to offset those costs. If EPA promulgates new regulations applicable to the unit, any incremental costs are added on to the cost burden for which the owner has already planned. The key point is that between the first year of operation and the year in which new rules take effect, the owner had no notion of the increase and did not set aside funds for such contingencies.

¹Because the Proposal will not take effect until 18 months after promulgation, we assumed that surveyed landfills with three or fewer years of remaining life (due to close in 1986, 1987, 1988, or 1989) will not incur any incremental costs for existing units; all will incur incremental costs for new units designed to comply with the new regulation.

If a landfill has an expected life of 25 years and has 10 years remaining, all the costs paid out over the first 15 years are considered sunk costs and do not affect the calculation of incremental costs resulting from the regulation. The difference that we want to measure is the increase in costs over the remaining life brought about by the new regulations. These could include capital costs for new equipment in the year the regulations become effective, incremental O&M costs in subsequent years of operation, incremental closure costs assuming more stringent closure requirements, continued monitoring costs after closure, and, possibly, corrective action.

The incremental present value costs of such requirements can be annualized over the remaining life of the landfill or some of the cost increases can be passed on to future landfills, particularly when publicly owned. However, the longer the remaining life of the unit, the smaller the incremental cost and the more likely that costs will not be passed on to the future. For the economic analysis, we use a comparison between the costs for the existing unit and the combined cost of an existing unit plus a new replacement unit to determine whether or not costs will be deferred. When the annualized cost of compliance at the existing unit is higher than the combined cost of a new unit (i.e., the existing unit has a short remaining life), costs are spread out into the future to mitigate the cost burden. When the opposite is true (long remaining life at the existing facility) and costs at the existing unit are lower than they will be for its replacement, costs are not deferred.

Combination of New and Existing Units

To develop a combined estimate of average annualized compliance costs from the regulatory options, the costs for existing units plus their new replacement landfills have been discounted to one present value that spans the existing landfill's remaining life plus the ongoing life of a new landfill that is replaced every 20 years (to account for unequal time periods). This present value is then annualized in perpetuity to calculate a level annual cost of the regulatory options. This figure is the best single point estimate of the overall cost impact of the options; however, it does not reflect the actual cash flows that would be required, particularly for capital costs. Instead, the annualized cost figure represents level annual payments as if the landfill owner borrowed funds to pay capital costs. This combined annualized cost estimate is used to calculate economic impacts.

Applying the Model to the Baseline and Regulatory Options

We described the regulatory options in Chapter III. To estimate the costs and effects of those options compared to the baseline, we ran the model once for each design specified by the provisions of the regulatory options and for the baseline. The cost specifications for each model run are described below.

Baseline

The baseline landfill is used to represent the current, typical unit that would be constructed and operated to manage municipal solid waste. The unit is designed and operated in accordance with good engineering practices. In developing specifications for the cost model, we used the generic inputs described above and made several design assumptions:

- Preconstruction studies and plans appropriate to support the facility (soil studies, road and site design, mapping, site development, and operating procedure plans) were included.
- The final cover consists of 18 inches of fill material, 6 inches of topsoil, and vegetation.
- No post-closure care occurs and no corrective action is undertaken.

Because the individual state's regulatory requirements are varied and difficult to categorize, it is complicated to establish a baseline that reflects the current program in each state. Nevertheless, EPA has collected information from states about their MSWLF regulations and has established that, in many instances, the state's requirements for ground-water monitoring wells are similar to those included in each of the regulatory options analyzed. In 24 states and territories (which include 2,702 landfills), therefore, we have assumed that ground-water monitoring wells are already required and no incremental costs result from the federal requirement. We also used data collected by EPA that indicate that 22 states (with 3,657 landfills) already have containment system requirements. For the Proposal only, we excluded incremental costs for liners and LCSs in those states.

We may still overestimate incremental compliance cost estimates to the extent that baseline design parameters like the vegetative cover are less stringent than those already required in some states. We have understated costs as well because we did

not incorporate all state requirements (e.g., run-on and run-off controls, gas monitoring, covers) that may currently exist for MSWLFs. Despite these possible errors, the adjusted baseline is representative of the present situation among the total regulated population of MSWLFs.

Proposed Rule: General Requirements

In Chapter III we described the performance standard that MSWLFs must meet at either the unit boundary (10-meter POC) or an alternative boundary (150-meter POC). To estimate costs we developed different design specifications for new and existing MSWLFs that we determined would enable owners and operators to meet the performance standards. We will describe the important differences between the specifications for the baseline and the Proposal, beginning with the elements that are common to all units under the Proposal.

Regardless of the design options (if any) chosen by the owner or operator to meet the performance standards under the Proposal, all new and existing units must:

- Develop procedures for excluding hazardous waste from the landfill;
- Collect data to allow for an assessment of whether or not the unit will meet the relevant performance standard;
- Monitor for explosive gases in the subsurface and in structures throughout the active life and post-closure care period;
- Include run-on and run-off controls;
- Prepare a closure plan;
- Provide for two phases of post-closure care;
- Demonstrate financial responsibility for closure, post-closure, and known releases;
- Monitor for ground-water contamination and perform corrective action when required; and
- Avoid some locations in siting new units or close existing units in those settings within five years.

All these requirements impose incremental costs above the baseline and, with the exception of financial responsibility, are included in the cost model estimates for all units under the Proposal. Hazardous waste exclusion and the closure plan are included as additional labor hours required to complete the tasks. The cost calculations for the other requirements are more complicated. As described in the Note To Readers, the modeling assumptions for ground-water monitoring and post-closure care do not reflect the details of those programs as proposed. We will describe below the differences between the Proposal and our model assumptions.

For gas monitoring, we assumed units would install monitoring probes 500 feet apart on two sides of the landfill's boundary. All landfills have at least four probes that are sampled twice per year. The cost of collecting hydrogeologic and other site data to simulate compliance with the performance standard is estimated to be \$12,000 per landfill. Run-on and run-off controls require construction of drainage ditches around the unit and a collection area for run-off.

Existing landfills in unstable locations must close within five years of the date of promulgation. We analyzed only one of the restricted locations described in the Proposal: Karst terrain. Survey respondents reporting that their landfill was in Karst terrain must close within five years, providing that alternatives for waste management are available.

Post-Closure Care. Post-closure care as proposed calls for development of a two-phase program. The first phase, which lasts 30 years after the unit is closed, includes maintenance of the cover, continued ground-water monitoring and gas monitoring, and leachate collection if appropriate. The second phase is less expensive and calls for continued gas and ground-water monitoring for a period to be specified by the state. The cost model assumes that the components of the first phase are conducted indefinitely. The result is that after 30 years have passed, the model overestimates post-closure care costs. The magnitude of the overestimate is quite small, however, for two reasons. First, these overestimates do not begin for at least 30 years and, given the discount rate, the present value of a current dollar in 30 years is only 41 cents; after 50 years the present value is 23 cents. The second factor is that gas and ground-water monitoring (which do continue beyond 30 years in the Proposal) dominate post-closure care costs, especially at small landfills where they account for about 80 percent of the total annual cost. The error introduced into the cost estimates is therefore quite small, less than one percent for most landfills and well within the margin of error of the cost model itself.

Ground-Water Monitoring. For landfills in states where wells are not already required, we estimated the cost of a ground-water monitoring system consisting of one upgradient well cluster and a variable number of downgradient well clusters. The clusters include three wells that draw samples from different depths. The number of downgradient well clusters, which is keyed to the length of the downgradient boundary, ranges from 4 for the 10-TPD unit to 20 for the 1,500-TPD unit. To account for the five-year phasing in of the monitoring requirements, we assumed that the costs for the wells would occur in the first year for 20 percent of the landfills. Each year, another 20 percent begin monitoring until all are in compliance. Landfills in states where adequate systems are already required will incur no capital costs for wells.

As with post-closure care, the modeling assumptions for ground-water monitoring samples differ somewhat from the requirements in the proposed rule. The rule calls for a two-phase monitoring approach. The first phase involves semiannual monitoring for 15 water quality parameters and over 50 specific constituents (including metals and volatile organic compounds). When these parameters show a change in ground-water quality, a second phase of monitoring begins. The second phase begins with a screen for a broad range of constituents, followed by quarterly sampling for each constituent that is detected above background levels. When any of those constituents is detected above trigger levels set by the state, the owner/operator must assess corrective measures.

The total monitoring costs estimated by the model for the Proposal are likely to be underestimated. The modeling assumptions differ in terms of the constituents sampled at various stages of the facilities' lifetime. We modeled three phases of monitoring in the RIA while the current Proposal calls for only two phases. The Proposal's first phase essentially combines the first two modeled phases (with per sample costs of \$60 and \$520 respectively). The Proposal phase one costs are estimated at \$644 per sample, so the model underestimates compliance costs for this phase of monitoring.

The Proposal's second phase of monitoring includes the same constituents modeled in the RIA for phase three, but the Proposal calls for an initial scan of these constituents followed by regular monitoring for those detected above threshold levels. (The states will specify when the complete scan should be repeated.) Because the actual constituents identified and monitored will differ by site, the actual cost of this aspect of the Proposal is uncertain, but it will be lower than modeled in the RIA. We have overstated sampling costs for phase two in the

Proposal to the extent that subsequent monitoring will address a relatively small subset of parameters tested in the initial scan.

Overall, the RIA underestimates phase one costs under the Proposal and overestimates phase two costs. We believe the net effect is that the RIA underestimates actual sampling costs that would be incurred under the proposed rule.

Finally, when the Risk Model indicates that constituents have appeared above trigger levels at the POC, costs are included for assessing and implementing corrective action. Because their incidence depends on landfill performance, these costs are modeled as part of the risk model. The corrective action cost methodology is discussed later in this chapter.

It is important to note that states that implement the program will have flexibility to tailor these requirements, for example, frequency of monitoring during the post-closure care period and well placement.

Several additional requirements, which differ between new and existing units, depend on whether or not the MSWLF meets the relevant performance standard and are described below.

Proposed Rule: Requirements
Based on the Performance Standards

In addition to the general facility standards presented above, certain design features may be necessary so that the MSWLFs can meet the relevant performance standard. As discussed in Chapter III, the proposed rule does not explicitly require any of these landfill designs, but it does describe that the cover, containment, and leachate collection systems will have major effects on ground-water quality.

To model costs and effectiveness, we assigned landfills to specific designs, based on the simulated performance of landfills in a range of environmental settings (described later in this chapter). To model the effect of the performance standard on MSWLFs, we estimated baseline risks in all the environmental settings simulated in the Subtitle D Risk Model.

We assumed, for purposes of this analysis only, that all landfills would be required to meet a 10^{-5} design goal (chosen from the allowable protective range of 10^{-4} to 10^{-7}). The landfills with risks below 10^{-5} given the baseline design (unlined with a vegetative cover) were excluded from any further design requirements and from corrective action since risks at these

units would never exceed the 10^{-5} threshold. Those with higher risks were assigned to increasingly stringent designs, as discussed below.

New Units: Design Assignments. New units are subject to all the general facility standards and may also be subject to design standards to ensure compliance with the design goal. To assign landfills to designs, we estimated the risks from landfills at the appropriate POC under increasingly stringent designs. Those that did not meet the design goal of 10^{-5} under baseline conditions were modeled assuming a synthetic cover system. If the unit would still not meet the design goal, we estimated risk assuming a synthetic cover system plus a synthetic containment system with leachate collection. Landfills that still could not meet the performance standard were targeted for corrective action.

We conducted this screening exercise for both the 10-meter and 150-meter compliance points and present the results in Figures IV-1 and IV-2 respectively. Figure IV-1 shows that at the 10-meter POC, 61 percent of the MSWLFs met the 10^{-5} design goal with an unlined unit with a vegetative cover. We then estimated risks for the remaining units with a synthetic cover; 11 percent of the total met the design goal with the cover system, but another 28 percent did not. This final group was assigned to a design with synthetic cover and containment systems along with leachate collection. The figure also shows that 11 percent of the total would still not meet the design goal; these are the units where corrective action will be triggered at some point in the future. We will discuss corrective action in more detail later in the chapter.

Figure IV-2 shows the corresponding estimate for landfill designs given that the point of compliance is at an alternative boundary, set 150 meters from the unit. Given the greater distance to the compliance point, we would expect more landfills to pass the first screen and, indeed, 79 percent of the MSWLFs had risks below 10^{-5} with an unlined, vegetative cover design. An additional 8 percent met the design goal with only a synthetic cover; 8 percent met the standard with a synthetic cover and synthetic liner; and the remaining 5 percent, even with the most stringent design, still did not meet the design goal and will eventually trigger corrective action.

The specific designs we modeled were chosen to represent possible combinations of engineered components. They are not specifically required by the rule, nor do they represent the only designs that might be chosen to meet the performance standard. They do, however, describe design features that would be applicable and effective in a wide range of settings.

Figure IV-1
Assignment of Landfills to Design Requirements
Proposed Rule: 10-Meter POC

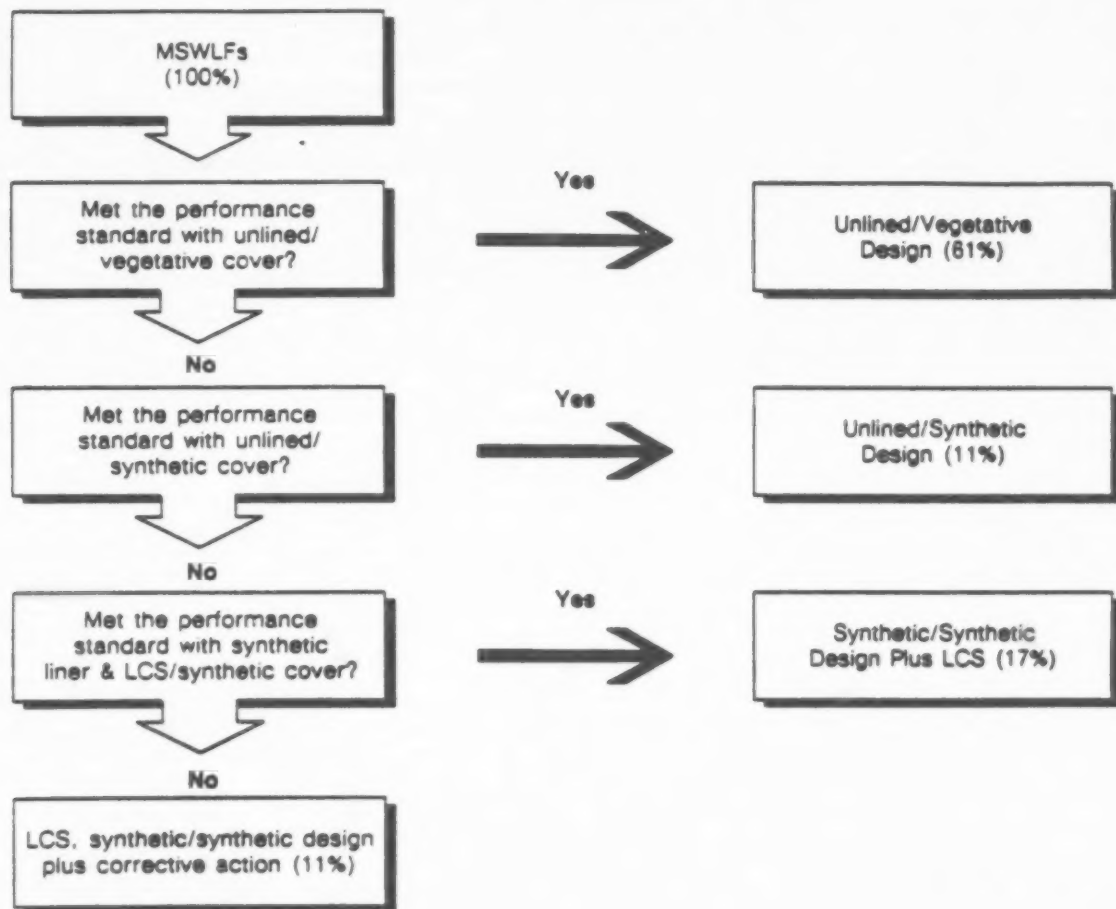
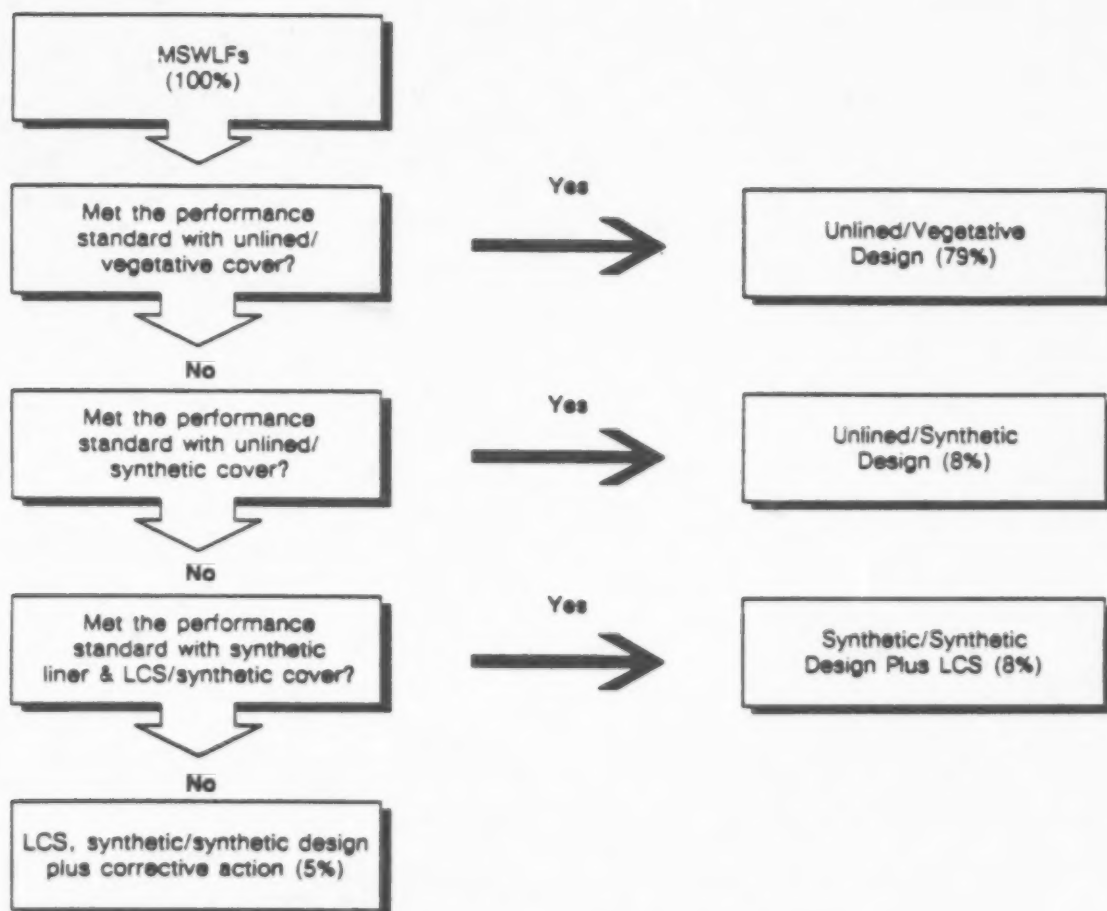


Figure IV-2
Assignment of Landfills to Design Requirements
Proposed Rule: 150-Meter POC



New Units: Design Components. The synthetic cover includes 12 inches of fill immediately above the waste, geotextile support fabric, a 30-mil synthetic layer, 12 inches of sand for drainage, geotextile filter fabric, topsoil, and vegetation. This cover system, including design, engineering, and quality assurance fees, is estimated to be three times more expensive per square meter than the baseline, vegetative cover (approximately \$27 per square meter versus \$9 per square meter).

The synthetic containment system includes a leachate collection system. The design includes 12 inches of fill directly beneath the waste, geotextile filter fabric, 12 inches of sand that includes the leachate collection system piping, a 30-mil synthetic liner, and geotextile support fabric. All collected leachate is trucked to an off-site POTW, the most common management option reported in the survey.

New Units: Adjusted Costs for Liners. The final point to make regarding designs for new units is that, as with groundwater monitoring, some states already have regulatory requirements for liners and leachate collection systems. To "credit" the cost estimates for landfills in these states, we adjusted the incremental cost for landfills that (1) were shown in the analysis to need a synthetic liner and leachate collection system and (2) were in one of the 22 states that EPA selected as having roughly equivalent liner and leachate collection system requirements. Landfills that meet these two criteria were assigned costs for the unlined/synthetic cover design so that the incremental costs imposed as a result of the Proposal would be more accurate. This adjustment was made only for the Proposal and only for costs. Incremental benefits were not adjusted downward.

Existing Units. EPA selected a different performance standard for existing units: to prevent infiltration. As a result, the only design option we modeled is the use of a synthetic cover system. The cover is the same described above for new units.

To assign existing landfills to designs, we relied on the modeling used for new units (since the risk model only simulates the performance of new units). We assumed that if a new, baseline unit met the design goal at the relevant compliance point, then existing units at the same site would meet the "prevent infiltration" performance standard. All others would install a synthetic cover system. Using the 10-meter point of compliance, 61 percent of the units met the performance standard with no liner or synthetic cover; the remaining 39 percent were assigned a synthetic cover. Given the 150-meter POC, 79 percent

of the landfills would meet the performance standard with no liner and a vegetative cover. The remaining 21 percent were assigned a synthetic cover. The incidence of corrective action at existing units is described in Chapter V.

Alternative 1: Subtitle C
Containment and Cover Systems

Under this Alternative, uniform standards are imposed on all landfills, and, therefore, no costs are included to determine compliance with the performance standard. The Alternative goes beyond the proposed rule for new units in two areas: containment systems and cover systems. Existing unit requirements are the same as for new units except that the containment system and leachate management system requirements do not apply.

The system of ground-water monitoring wells is assumed to be the same as in the Proposal, and landfills in states with current monitoring programs will incur no incremental costs. The sampling parameters, however, are different. The modeled cost per sample increases from \$60 (for the first phase of monitoring) under the Proposal to \$520. This set of parameters is not as complete as the Phase I parameters required under the Proposal. Finally, unlike the Proposal, ground-water monitoring is not phased in, but begins on the effective date of the regulation.

The cover placed over new and existing units will comply with current RCRA Subtitle C requirements described at 40 CFR 264.310. We modeled this cover as a composite system consisting of two feet of recompacted clay, geotextile support fabric, 30-mil synthetic material, 12 inches of sand, geotextile filter fabric, and six inches of topsoil. The difference between this design and the synthetic cover used in the Proposal is the addition of a clay layer. The change adds about 33 percent to the total cover cost if the clay is available on site. If clay is brought from off site, the cost of the composite cover is almost twice that of the synthetic cover. On-site clay was assumed to be available when clay or sandy clay was reported as the primary or secondary soil type in the EPA Municipal Landfill Survey.

Finally, for new units, the containment system design is similar to that specified under Subtitle C in Section 264.301. It consists of a bottom, composite liner and a top liner designed to provide primary leachate collection. We specified that the system would include three feet of clay, a 30-mil synthetic layer, 12 inches of sand for a secondary leachate collection and detection system, another 30-mil synthetic layer, 12 inches of sand to include the primary leachate collection system,

geotextile filter fabric, and 12 inches of earth. This containment system is about two to three times more expensive than the synthetic system described for some landfills under the Proposal. Because the costs are sensitive to whether the clay is available on or off site, we estimated costs both ways. As with covers, we assumed that clay was brought from off site unless the landfill owner/operator reported in the survey that clay or sandy clay was available at the site.

Alternative 2: Categorical
Rule Based on Location

This option provides an alternative approach to the Proposal because it focuses on an engineered solution (i.e., specific landfill designs, keyed to location instead of risk). Under this Alternative, landfills are assigned to designs based on the local climate and hydrogeologic factors that control the potential for releases.

The general facility standards described for the Proposal are also added for the categorical Alternative. Monitoring is included for all landfills, but capital costs are subtracted for MSWLFs in states with existing ground-water monitoring requirements. Also, monitoring is phased in over five years.

In addition to the general facility standards, this option includes a range of design options, assigned to specific landfills based on site-specific information on the potential for releases to the ground water. We used information from EPA's survey of MSWLFs to assign designs to 621 landfills characterized by climate and hydrogeology. The results are then extrapolated to the population of 6,034 active MSWLFs.

Existing Units. The only design option we modeled for existing units is the use of a synthetic cover system at closure. This is the same system assigned to some units under the Proposal and is assigned in our analysis to landfills based on annual net precipitation. Annual net precipitation was defined as the sum of monthly mean precipitation for any one-year period minus the sum of monthly mean potential evapotranspiration for the same period. Since the goal of the cover is to minimize the infiltration of liquids into the waste, we decided that units with positive net precipitation, about 66 percent of the 6,034 MSWLFs, have a greater potential for infiltration and, therefore, are assigned this cover. All other landfills have the same vegetative cover that is used in the baseline, except that the general facility standards increase the quality assurance fees.

New Units. New units are assigned to one of seven different design categories, developed for the purpose of modeling costs and effectiveness. These designs were developed based on two principles:

- The design must prevent liquids from reaching the aquifer during the facility's active life and,
- The final cover must minimize leachate generation by minimizing the infiltration of liquid into the waste.

The designs we developed are not necessarily the only ones that would meet the performance standards. Given the site-specific nature of this Alternative, however, we were compelled to make assumptions about the designs to model its cost and effectiveness. We will describe how we assigned MSWLFs to the different designs and then summarize the number of landfills per design.

Cover Systems for New Units. The assignment of covers is the same as for existing units: MSWLFs with positive net precipitation were assigned synthetic covers; all other units will have a vegetative cover. As with the existing units, about two-thirds of the landfills have positive net precipitation and, therefore, synthetic covers.

Leachate Collection Systems for New Units. To prevent the release of leachate to the aquifer during the active life of the unit, this regulatory approach requires an LCS in areas of high annual precipitation (greater than 40 inches per year) and in areas with low precipitation if at least one of three conditions were met:

- More than one foot of leachate could accumulate at the bottom of the unit,
- The unit is located within the saturated zone, or
- The unit has a flexible membrane liner.

Any of these circumstances could result in a sufficient volume of leachate generation to threaten release to the aquifer during the operating life. Across the 621 landfills for which adequate data were available, we estimated that 75 percent would need an LCS to meet the standards. Thirty-four percent are in areas of high precipitation, and the remaining 41 percent met at least one of the three conditions listed above.

Containment Systems for New Units. Our assignment of containment systems to MSWLFs was based on meeting the requirement to prevent releases to the aquifer during the active life and on

the relative costs of various systems. Figure IV-3 shows the assignment of new landfills to the LCS and liner designs described for new units under the categorical Alternative. First, we will review liner assignments for units that also have an LCS.

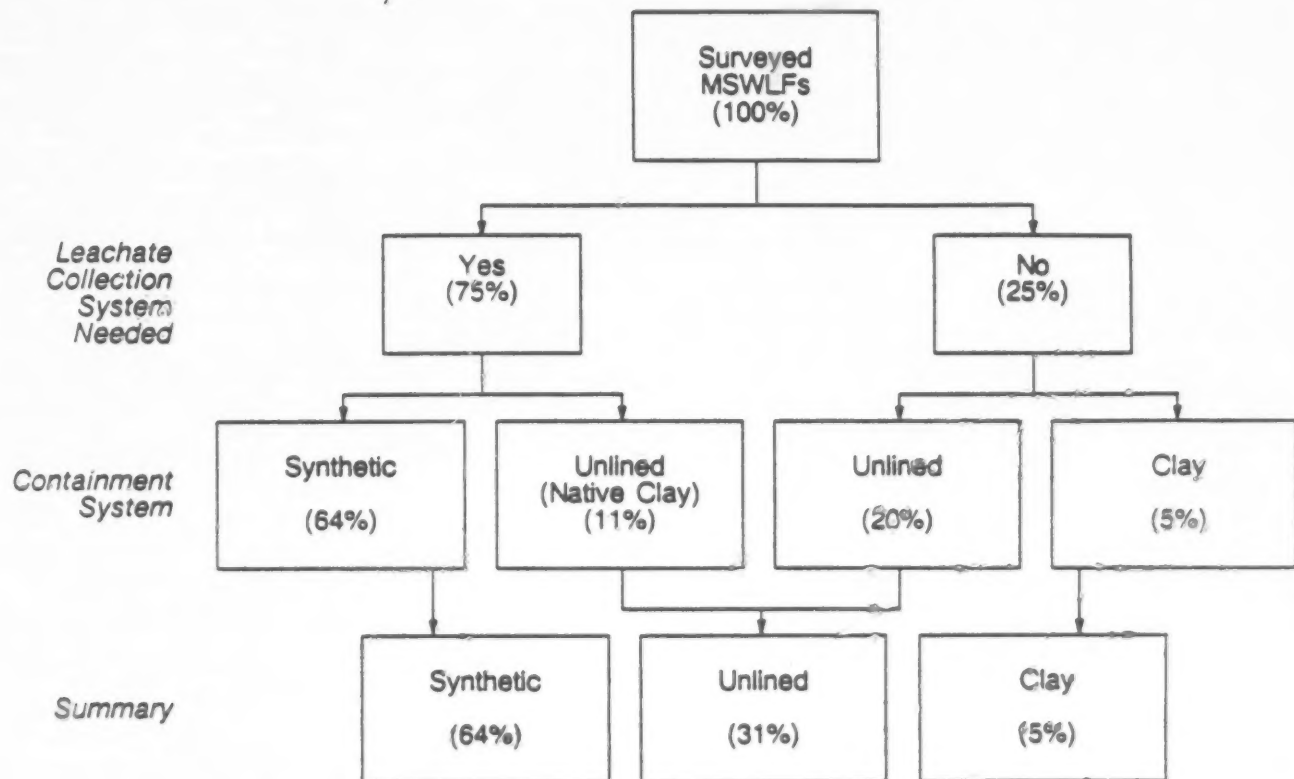
MSWLFs that are assigned an LCS may need to provide an impermeable layer to ensure that the LCS will efficiently remove leachate. If an LCS is installed over permeable material, the system will not be capable of removing an adequate volume of leachate before it permeates the soil. Of the 75 percent of landfills with an LCS, we estimated that 64 percent have soils that are so permeable that a synthetic liner would be required to achieve high LCS efficiency. The remaining 11 percent of the landfills are located over clay and do not need a synthetic layer as part of the LCS. In these cases the LCS is installed directly on carefully graded native soil.

For MSWLFs without leachate collection systems, we assigned containment system designs to protect against leachate reaching the underlying aquifer during the operating life. In these cases, we selected containment systems to delay the transport (increase the time of travel) of leachate from the unit. In most of the 25 percent of landfills without leachate collection systems, the native soils are sufficiently thick or impermeable to provide adequate delay for leachate that might leave the unit. Twenty percent of the total number of landfills, therefore, have no containment system required. The remaining 5 percent could achieve the necessary delay most efficiently by installing a clay liner; we determined that two feet of recompact clay would provide adequate delay to meet the criterion of no releases to the aquifer during the active life of the landfill.

To summarize these LCS and containment system assignments, Figure IV-3 shows that 64 percent of the MSWLFs will have a leachate collection system and a synthetic liner. An additional 31 percent will be unlined and 11 percent of those will have an LCS. Finally, 5 percent of the landfills will have no LCS, but will have a two-foot-thick clay liner to delay the travel of leachate from the unit to the aquifer.

Summary of Designs for New Units. Table IV-1 summarizes the various combinations of designs that we assigned to landfills. The synthetic/synthetic design with LCS is the most common design, assigned to 56 percent of the landfills. We should emphasize that these assignments are not meant to define the only possible interpretation of the categorical Alternative: they represent our best effort at specifying designs to meet the criteria presented earlier. This assignment was necessary to estimate the costs, impacts, and effectiveness of the Alternative.

Figure IV-3
Assignment of Surveyed Landfills to Containment System Requirements¹
Alternative 2



¹ Extrapolated from 621 surveyed landfills.

Table IV-1
SUMMARY OF DESIGNS FOR ALTERNATIVE 2

<u>LCS</u>	<u>Containment</u>	<u>Cover</u>	<u>Percentage¹ of MSWLFs</u>
No	Unlined	Vegetative	18%
No	Unlined	Synthetic	2
No	Clay	Vegetative	5
Yes	Synthetic	Vegetative	8
Yes	Synthetic	Synthetic	56
Yes	Unlined	Vegetative	4
Yes	Unlined	Synthetic	8

¹Does not add to 100 percent because of rounding.

Alternative 3: Statutory Minimum

This Alternative applies uniform criteria to new and existing landfills, but the requirements are much less extensive than for any other option. The only difference between this Alternative and the baseline is that we include incremental costs for ground-water monitoring during the active life and extended post-closure care period as well as corrective action costs as necessary. The capital costs for monitoring are waived for landfills in states identified as having monitoring requirements. We assumed that all monitoring would begin on the effective date of the regulation. The sampling costs are the same as those modeled for the Proposal; as described earlier, the per sample cost used in the model is much lower than that required by the Proposal.

Costs Dependent on Risk Model Results

The Subtitle D Risk Model estimates the releases and transport of contaminants through the unsaturated and saturated zones. We use components of the Risk Model to determine the need for corrective action, the costs of corrective action, and the need to shift from phase one ground-water monitoring parameters to phase two parameters.

Corrective Action

The corrective action cost submodel provides cost estimates for the design, construction, operation, and maintenance of corrective actions in response to releases from landfills. For this analysis, the corrective action technology (CAT) modeled for these units is limited to recovery wells; costs to replace water supplies in lieu of plume cleanup are estimated elsewhere in the model and are used for some "corrective actions" at existing units.

Our general approach for modeling corrective action was to assume that plumes from new landfills would be completely cleaned up while plumes from existing landfills would be addressed more flexibly. To include in the modeling some recognition of the flexibility available for corrective action, we modeled corrective action for existing units under two approaches based on plume size. The first is an active plume cleanup similar to the approach modeled for new units. The second approach relies on replacing ground-water supplies instead of immediately cleaning up the plume. In Chapter V we report the fraction of MSWLFs assigned to each of the approaches. The methodology for estimating replacement costs is given later in this chapter under the discussion of the resource damage component of the Subtitle D Risk Model.

It is difficult to capture accurately the range of flexible responses to the rule; our assumptions are simply estimates made for modeling purposes. Our assumptions about corrective action modeling are described in the Risk and Resource Damage section of the chapter.

Corrective Action Costs. The Risk Model estimates the total present value of costs for the corrective action based on the size of the plume and the duration of the action. The methodology used for computing corrective action costs is briefly described below.

Recovery well systems are designed to remove contaminated ground water, treat it, and then return the water to the aquifer or discharge it to surface water. The systems are installed above the plume and pump ground water from the entire plume. We assume that the recovery wells begin operating one year after corrective action is triggered. The length of time the wells are operated depends on the mobility of the constituents in the ground water, the flow rate of the aquifer, and the rate at which contaminated ground water is removed.

Recovery well costs include direct capital costs, indirect capital costs, and O&M costs. The first step in computing the costs of recovery wells is to calculate the dimensions of the floating plume in the year it is detected. The plume discharge rate is calculated based on flow field parameters (porosity, velocity, and thickness, as described later in the chapter). The pumping rate, pumping duration, number of wells necessary, and well depths are then computed as a function of the plume discharge rate. We calculate direct capital costs for wells and effluent treatment plants based on well dimensions and the pumping rate. Indirect and O&M costs are estimated as a percentage of direct costs. As with other costs, these are incurred as a stream and discounted to year zero of the simulation period.

Choosing a Corrective Action. After the model calculates the cost and effectiveness of each corrective action, we select as the CAT of choice the lowest-cost action that reduces contaminant concentrations below the target level at the 10-meter monitoring well. In previous model runs, recovery wells were found to be the least-cost CAT for virtually all plumes. Consistent with this finding, recovery wells were selected as the chosen CAT for this analysis.

Assigning Corrective Action Costs to Landfills. The Subtitle D Risk Model provides the outputs used to assign corrective action costs to landfills. The model analyzes a range of typical environmental settings, defined by climate and hydrogeologic factors discussed later in this chapter, and it identifies the landfill sizes and designs in these settings that are likely to trigger corrective action (i.e., where constituents exceed trigger levels). We calculate from the model results the fraction of landfills in each setting that will trigger corrective action and the weighted average cost they will incur. The costs are a function of the unit size and design, CAT, net infiltration, depth to ground water, and ground-water flow rate. Finally, we assign these costs to individual landfills based on survey information that indicates those most likely to have high risks (e.g., those with short times of travel for constituents to nearby wells). In Chapter V we present the incidence and costs of corrective action under each option.

Ground-Water Monitoring

Under the Proposal, the second phase of monitoring for an expanded list of parameters begins when phase one parameters show a significant change. We used a time-of-travel approach to determine (conservatively) when contaminants would appear at the

monitoring well (located either 10 meters or 150 meters from the unit depending on the relevant POC). The approach was applied only to new units because of the complexity involved in modeling travel time for existing units with widely variable starting dates. For units in settings where contaminants appear at the monitoring wells, we imposed a higher monitoring cost from the initial year of detection until the end of the post-closure care period. If triggers are exceeded, then corrective action begins. As described earlier the model understates the magnitude of the monitoring costs for this early phase of monitoring.

As with corrective action, states may take into account the resource value of the ground water and modify the monitoring requirements, although we did not capture this in the modeling.

Assignment of Costs to Actual Landfills

The cost analysis produces a results matrix of year-by-year capital and operating costs for each design option by each of the seven model landfill sizes, which range from 10 to 1,500 TPD. Our next step was to use these cost estimates to project actual compliance costs for the 621 active landfills in the survey. These landfills provided sufficient information on their environmental setting to allow us to assign designs for the Proposal and categorical Alternative. To assign costs, we developed a cost function for each design option that related incremental compliance cost per ton of waste to landfill size. With this function we could then enter the actual size of an active landfill and directly estimate the incremental cost of a specific option for that landfill. For options like the Proposal that include several unique landfill designs, separate cost functions were developed for each design so that each landfill could be costed according to its assigned requirements. Separate cost functions were also developed for new and existing facilities.

The incremental cost for new facilities was calculated based on a 20-year operating life. For existing facilities, the remaining life of the landfill as reported in the survey was employed to estimate compliance costs.

Key assumptions in assigning costs to the 621 active landfills were as follows:

- Real discount rate is 3 percent.
- Remaining life at existing landfills is as reported in the survey, except:

- Limited to 50 years
- When not reported, assumed to be eight years (the median remaining life as reported in the landfill survey)
- New MSWLFs have a 20-year life.
- Costs for existing landfills are deferred beyond the closure date when the levelized cost across the existing landfill plus a new landfill is lower than full cost recovery at the existing landfill.
- Waste generation is assumed to be 0.68 tons per person per year.
- Landfills operate 260 days per year.

Developing National Cost Estimates

Once the incremental compliance costs for each of the surveyed landfills were calculated, they were scaled or weighted up to national cost estimates. The weighting factors (developed as part of the Office of Solid Waste's Solid Waste (Municipal) Landfill Survey or MSWLF Survey) differ because the sample for the survey was stratified based on landfill size. The sample included a higher proportion of large facilities (greater than 500 TPD) than small ones. Therefore the weighting factor for small landfills is greater than the one for large units. These factors relate the number of the landfills surveyed to the current universe of landfills. The weights are as follows:

	<u>Below 500 TPD</u>	<u>Greater than or Equal to 500 TPD</u>	<u>Total</u>
Universe	5,784	250	6,034
Survey	552	69	621
Weight (universe/survey)	10.47	3.62	

This means that each cost for landfills below 500 TPD is counted 10.47 times in aggregating to the total cost for all MSWLFs. It should be noted that these weights are preliminary and would be revised if we included all survey responses. However, they do provide a good intermediate means of estimating aggregate national cost estimates.

ECONOMIC IMPACT ANALYSIS

Overview of Approach

The economic impact analysis assesses the impacts of alternative regulatory approaches on those who will face increased costs, and analyzes how those impacts will be distributed.

As Chapter II indicated, over 80 percent of all landfills that handle MSW are owned by local governments, including counties, cities, towns, and villages. The governments that own these landfills will bear the initial impacts of new Subtitle D regulations. These governments will then pass the increased costs on to their own citizens and to neighboring governments that might also use the landfill. Governments may pass on higher costs in the form of increased taxes or fees or decreased services of other types if the community is constrained by its budget. Ultimately, the households that use the landfill to dispose of their waste will most likely pay the increased costs of landfill operation.

Approximately 15 percent of all MSWLFs are owned by private operators. The MSW handled by these landfills comes from governments or households that contract for the landfills' services. Because all landfills will experience higher costs as a result of new regulations, most private operators will be able to pass these higher costs on to the governments and households that they serve. Private landfills that have much higher regulatory costs than average may have some difficulty passing these costs on to their customers if they are located near resource recovery facilities or other landfills that could serve the same communities at a lower cost. When costs cannot be passed on, the private operator will incur an economic impact that could force the landfill to close. For the economic analysis we assume that landfills will pass through costs and that the resulting economic impacts will accrue to municipalities and households. While this assumption is valid in the majority of cases, we supplement the economic analysis with a review of cost impacts on the 15 percent of landfills that are privately owned.

Our approach for conducting the economic impact analysis is divided into two steps. In the first step we assess the ability

of municipalities² to pay for increased landfill costs, since these entities are most likely to face higher solid waste disposal costs in the short run. In the second step we review the ultimate impact of new regulations on the citizens of municipalities, since they will pay for higher landfill costs, either immediately or over a longer period as taxes are raised or other services reduced. These two analyses are conducted sequentially to determine the overall economic impact on households from regulatory options affecting municipal solid waste disposal landfills.

The analysis of economic impacts on municipalities is further divided into two elements. The first element of the municipal impact analysis involves assessing the impact of regulatory costs on these municipalities by calculating annual costs as a percentage of total municipal expenditures and comparing this ratio with a predetermined threshold level.

The second element is an assessment of the baseline financial capability of the community. Unlike the measure of costs as a percentage of expenditures, which addresses the magnitude of costs, the financial capability element considers communities' ability to absorb regulatory costs (i.e., their practicable capability). For simplicity, this practicable capability measure can be thought of as a composite score that characterizes economic vitality (e.g., population growth, level of poverty), debt burden (e.g., debt per capita), and financial management (e.g., operating surplus/deficit, expense levels) of a community. The score categorizes communities' financial capabilities as weak, average, or strong. To perform these analyses, we compiled a detailed database on the financial and demographic characteristics of local governments, as described below.

This approach for conducting community impact analyses was selected because the overall financial capability score of a community will not change significantly with the imposition of costs: increased operating expenditures for MSW management will not change many of the indicators used to measure financial capability. In addition, it would not be appropriate to presuppose the reaction of a community to higher landfill costs. Some communities will increase taxes or fees, while many others will

²The terms "municipalities" and "communities" are used in this report to identify local governments responsible for solid waste disposal. These governments include counties, cities, towns, and villages. Many states and the U.S. Department of the Census use the term "municipality" to refer only to incorporated jurisdictions that satisfy certain conditions.

reallocate available funds to meet higher landfill costs. In the area of debt impact, it is also not clear how a given project will be financed. Many communities will use pay-as-you-go financing as they always have, others will take on debt, and the remainder will turn to private contractors who will raise their own capital.

The second half of the impact analysis focuses on the ultimate ability of a municipality's citizens to pay for regulatory costs. This part of the analysis assesses the absolute and relative impact of regulatory costs on households. The absolute impact is measured in terms of total cost per household. The relative impact is measured using costs as a percentage of median household income. In this section of the report we first describe the economic impact measures computed for communities and individuals. Second we describe the development of the database and measure of communities' financial capability.

Measures of Economic Impact

To evaluate the economic impact of additional regulatory costs, we examined several approaches that measure economic impact, including evaluating increased costs relative to communities' and households' wealth, income, and economic potential. Such analyses are commonly used by other analysts and have been used by EPA in other municipal programs.

For example, EPA's Construction Grants Program has used a number of measures to identify potentially high-cost projects. These measures include:

- Total annual cost per household and as a percentage of median household income,
- Capital cost per household,
- Total annual cost as a percentage of total personal income,
- Total and general obligation debt as a percentage of fair market value of property, and
- Outstanding debt per capita.

Some of these measures, such as the debt measures, are more meaningful when assessing impacts on a single governmental entity (as in the case of the Construction Grants Program), because the analyst can better determine the extent to which the community will actually rely on debt financing.

In our analysis we examined three measures of impact:

- Total annualized cost as a percentage of expenditures (CPE),
- Total annualized cost per household (CPH), and
- Total annualized cost per household as a percentage of median household income (CPMHI).

The first measures impacts on municipalities, while the second two focus on impacts on individual households.

Cost as a percentage of expenditures provides a clear indication of how expensive the regulations will be relative to communities' current operating budgets. Most communities, except those already financially weak, can accommodate small increases in expenditures with relatively little disruption. Even strong communities, however, may have difficulty adjusting their budgets to accommodate large increases in expenditures, especially in the short run. We address in detail communities' ability to cover these costs in a later section.

Communities typically spend less than 1 percent of their budgets on solid waste disposal. Calculations using data from EPA's Municipal Landfill Survey, for example, indicate that municipal solid waste disposal costs average approximately 0.5 percent of communities' total expenditures. In comparison with other municipal services, costs at this level represent a very small obligation. For example, Table IV-2 shows the average cost for other selected services as a percentage of total community expenditures in 1982, according to the Census Department.

Table IV-2
COST FOR OTHER SERVICES

<u>Service</u>	<u>Average Percentage of Expenditures</u>
Education	36%
Police	5
Sewage disposal	3
Fire protection	2
Solid waste collection and disposal	1

On the basis of these data, we established a severe impacts threshold at 1 percent of total community expenditures. If incremental costs of compliance for a community exceed 1 percent of total expenditures, we describe the impact as severe. Nevertheless, as indicated by the level of spending on other services, even our "severe" impacts are relatively minor in absolute terms.

Cost per household and cost per household as a percentage of MHI measure the impacts of the regulations on the people who will ultimately pay these costs and who actually generate the majority of municipal solid waste (as Chapter II indicated, the majority of the waste stream at MSWLFs consists of household waste).

Two threshold levels are used for cost per household, one that provides a comparison to households' current expenditures on MSW and one based on MHI. Estimates from the MSWLF survey indicate that households in most communities spend between \$10 and \$30 per year on MSW disposal, excluding collection and transportation costs. These costs may be understated somewhat because they are reported annual expenditures and may not include amortization of capital equipment and land. We will discuss these estimates further in Chapter V. An incremental regulatory cost of \$100 per household per year was selected as a threshold for moderate impacts. Although this cost represents a large percentage increase in many households' disposal costs, it represents a relatively small absolute charge. A threshold of \$220 per household was used to measure severe impacts. This threshold was calculated as 1 percent of the MHI of all the communities in the analysis. We recognize, however, that as MHI varies, the CPH threshold in the community would vary as well. For that reason, we also computed CPMHI.

EPA's Construction Grants Program established threshold levels for CPMHI. Their criteria ranged from 1.0 percent of MHI for low-income communities to 1.75 percent of MHI for high-income communities.³ A threshold of 1.0 percent has been adopted in our analysis as a significant level of burden.

Estimation of Compliance Costs for Municipalities

To calculate the measures of economic impact discussed above, we first had to determine the proportion of landfill compliance costs that would be passed on to municipalities and their

³Financial Capability Guidebook, U.S. Environmental Protection Agency, Office of Water Programs Operations (February 1983).

citizens. To achieve this, we analyzed the subset of municipalities that are served by the 621 surveyed landfills for which we had prepared compliance cost estimates. The municipalities participating in these landfills were identified in several different ways. First, the survey form requested a listing of jurisdictions served. This information was useful, but often nonspecific or incomplete. Responses ranged from specific municipalities to "portions" of towns or counties. The municipalities listed in the survey that were also included in the comprehensive municipal database were identified as valid landfill participants. If a municipality could not be located in the municipal database, it was not included in the economic analysis, since we had no direct way of obtaining its demographic and financial information.

We utilized several information sources to identify additional municipalities that are probably served by the landfills in the survey, but were not listed in the survey responses. First, we compared survey responses to our previous assignments of municipalities to all landfills using a complete listing of landfills from the EPA State Census of Landfills, which contains 7,645 landfills. This assignment of municipalities to all the landfills was done with a distance-minimizing algorithm that used the latitude and longitude of municipalities and the landfills. The distance algorithm assigned municipalities to the closest landfill, while imposing some restrictions on which landfills could serve which municipalities (e.g., limiting crossing state lines). The resulting landfill assignments were used to supplement the MSW landfill survey data.

In the many cases where the survey respondents indicated that the landfill served the "entire county," we were able to assign municipalities located within those counties to that landfill. In cases where no information was provided on the municipality served, the city where the landfill is located was at least assigned as one of the municipalities served.

The next step was to ensure that we did not assign too many municipalities to the landfills, either through our additional assignments or through assigning the entire population of a large city to a given landfill, while only a portion of that population is actually served by that landfill.

We used population and waste quantity information as a check against this potential problem. The sum of the populations of each town assigned to a landfill was compared with the reported population served by that landfill. When population assigned exceeded the reported population served, adjustments were made by eliminating municipalities that had been added using the supplement assignments. When the population served by the landfill was

not provided in the survey, we utilized the waste quantity received information to test the reasonableness of the population we had assigned to the landfill. We calculated waste generated by this population using the estimate of 0.68 tons of waste per person per year and compared it with the waste quantity reported in the survey. When these figures seemed unreasonable we checked reported waste quantity and our estimated waste quantity generated against reported landfill capacity. These checks, which were based on population served, waste quantity generated, and landfill size, were used successfully to ensure that municipalities were properly assigned to landfills.

The linkage between landfill compliance cost estimates and the participating municipalities then served as the basis for cost estimates used in the economic analysis. The total number of municipalities identified as using the surveyed landfills was 1,810. Thus, just as the surveyed landfills provide a sizeable sample of all MSWLFs, the linkage between landfills and municipalities identified a similar sample of municipalities for the impact analysis. The municipalities identified did not cover all the 621 landfills analyzed, but did cover 532 (86 percent) of them.

Once the subset of municipalities was determined, the incremental costs at the landfills were apportioned from the landfills to the municipalities. This was done on a unit cost basis (dollars per ton) to account for imperfect matches between a landfill and the exact number and size of the jurisdictions served and for the potential overlap of landfill services with landfills that were not included in the survey. The apportioned compliance cost estimates were then used to measure economic impact on the municipalities and their citizens.

The results from the impact analysis are weighted up to national totals for all 29,017 municipalities. The weights were based on the population size and financial condition (described in the next section) of the municipalities included in the sample and were calculated by dividing the total number of municipalities in a size and financial condition category by the corresponding number of municipalities in the impact analysis. The final weights applied to each category are presented in Table IV-3.

Table IV-3

SCALING WEIGHTS USED TO EXTRAPOLATE FROM
THE MUNICIPAL SAMPLE TO ALL MUNICIPALITIES

Population Size	Financial Condition		
	Weak	Average	Strong
Less than 500	22.8	22.4	18.4
500-1,000	17.1	18.0	14.2
1,000-2,500	20.3	16.0	16.4
2,500-5,000	13.9	12.8	17.0
5,000-10,000	10.7	15.6	15.6
10,000-25,000	9.4	13.3	14.3
25,000-50,000	11.5	13.7	10.7
50,000-100,000	7.7	13.9	7.5
Greater than 100,000	5.8	6.6	11.0

Source: TBS calculations.

Database Description

Developing a database on financial and demographic characteristics of municipalities was the first step in conducting the financial capability analysis. This section, which describes the database, is divided into four parts: sources of data, number and type of jurisdictions included, complexities encountered, and financial and demographic information.

Sources of Data

As we began to build the database of financial and demographic characteristics, we examined a number of commercially available data sources. These are sold by private vendors, which include CAC International, Inc.; Moody's Municipal Research Department; and Donnelly's Marketing Service. They all repackage Census Department data for various marketing purposes. We found that they were generally incomplete for this analysis. This led us to choose the Census Department, which is the original source of all the commercially packaged data, as the data source for our analysis.

The two primary data sources for the database are the 1982 Census of Governments and the 1983 County and City Data Book. Complete government censuses are conducted every five years, so the 1982 Census of Governments data are the most recent information available on local government finances. Our demographic

information comes primarily from the 1983 City and County Data Book, which was chosen so it would closely match the other census data. We obtained the data from both sources on magnetic tape, matched the different governmental unit coding systems, and merged the information into one large database.

After we compiled the initial database, we talked extensively with the Chief of the Census Department's Government Finance Branch, to ensure that our interpretation of the data is correct. In addition, we spoke with another expert on census information at Syracuse University.

Number and Type of
Jurisdictions Included

The complete database includes selected information on revenues, expenditures, debt, and demographic characteristics for 29,017 governments. The 29,017 governments were chosen after we examined every state individually and determined the main providers of local government services in each.

The primary governments in the database are in four categories:

- County,
- Municipality,
- Township, and
- Rest of county.

We use the "rest of county" category as an accounting tool in counties that are dominated by one or more municipalities but that have a significant population not contained in one of these incorporated areas. A rest-of-county entry exists wherever 20 percent or more of the population, or more than 5,000 people, do not live in incorporated areas. The full county generally is not the primary provider of local government services, which is why so few counties are included in our database of primary local governments (Table IV-4).

Table IV-4		
BREAKDOWN OF PRIMARY GOVERNMENT ENTITIES		
	<u>Number</u>	<u>Percentage of Total</u>
County	197	0.7%
Municipality	17,618	60.7
Township	8,780	30.3
Rest of county	2,422	8.3
Total	29,017	100.0%

The number and type of governments in the database vary greatly by state. For example, Washington, D.C., is counted as a single municipality, while Pennsylvania contains 2,564 townships and municipalities. The New England states tend to have many municipalities and towns, since the states are composed almost entirely of incorporated areas. Conversely, the southern states have stronger county governments, and much of the population lives outside the boundaries of incorporated areas.

Figure IV-4 illustrates the size characteristics of the 29,000 governments of interest. The chart identifies the number of governments by a variety of population size categories. It illustrates the very large number of small entities, particularly in light of the fact that the regulatory flexibility analysis guidelines suggest a population cutoff of 50,000 in defining small governments.

Figure IV-4
NUMBER OF GOVERNMENTS
PROVIDING GENERAL GOVERNMENT SERVICES
BY SIZE CATEGORIES

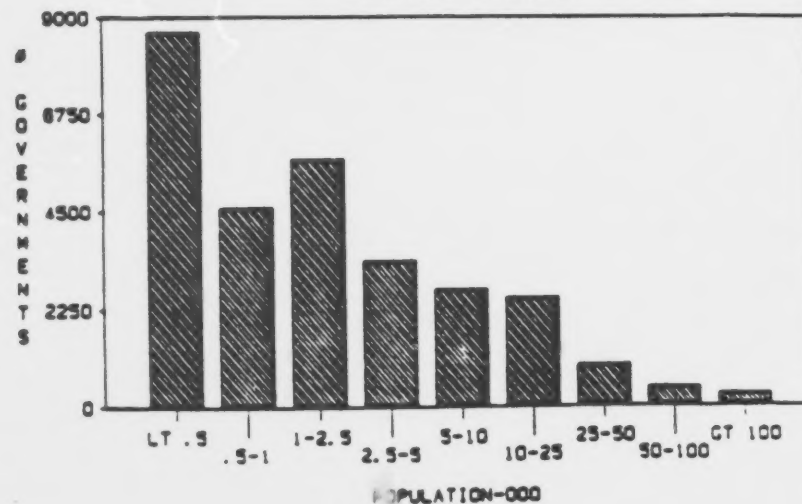
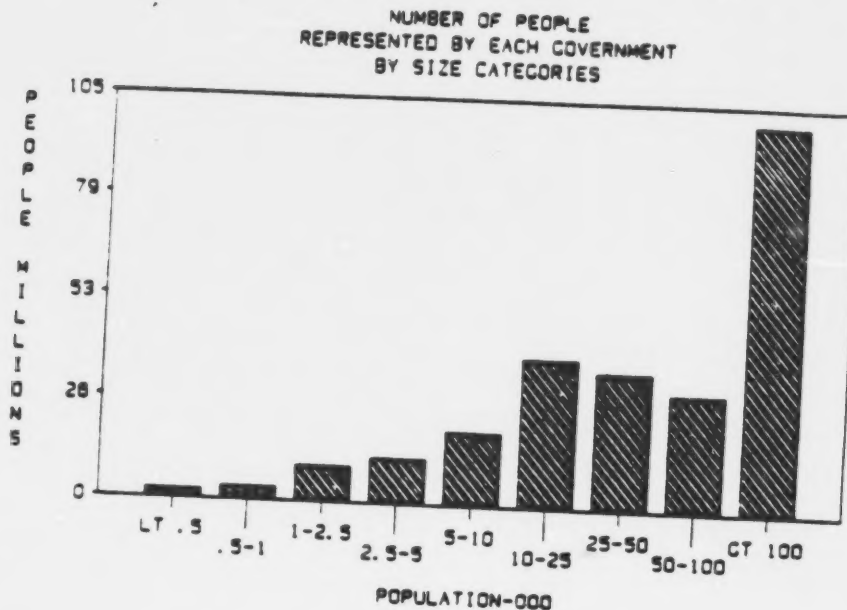


Figure IV-5 presents the number of people that live in each government size category. Here it becomes apparent that a substantial number of all people in the United States live in the limited number of large metropolitan areas. Conversely, the thousands of small towns represent a relatively small fraction of the total U.S. population.

Figure IV-5



Complexities Encountered in Building the Database

We faced two major obstacles in creating the database: allocating county and special district financial data to smaller governments, and coping with the wide variation in governmental organization found across the country. The first problem occurred because counties (and special districts) provide some but not all local government services. Thus, the revenue, expenditure, and debt statistics for the individual municipalities do not accurately describe the financial situation of their residents, since the residents are also responsible for a share of the county's, and in some cases special district's, revenues, expenditures, and debt. This was a fundamental problem, which we solved by allocating county and special district financial data to smaller governments on the basis of population, a process we

call "allocating down." When these figures are combined with those already recorded for municipalities, they provide a more accurate financial characterization of a municipality's residents.

The problem of variation in governmental organization has many forms. Although organizational forms and terminology tend to be fairly consistent in a given region, this is not always the case. In disparate areas of the country, the inconsistencies are more marked.

These problems are most evident in the classification of towns and townships and in states where counties rather than municipalities are the major supplier of local government services. For example, Indiana has township governments covering all its area and population. Naturally, these overlap with many other governmental units in the state, and debt is allocated to Indiana's population through several overlapping levels of government. Indiana, however, is the only state where townships cover the entire population. In five other states, operating townships comprise all territory other than that served by municipalities. Maine would also fall into this last category, but it contains "unorganized territory," which lacks any local government. In ten other states, some--but not all--municipalities operate in a territory that is also served by townships.

In some instances, townships share exact geographic borders with the overlapping governmental unit. In these cases, the names and populations of the two governments are often identical, and financial information can be allocated equally to all persons in the region. This greatly simplifies the process of assessing a community's financial health. Frequently, however, the overlapping government units do not exactly coincide. In these cases, the allocation of debt and revenue and the financial capability assessment are substantially more difficult to perform.

Several states are characterized by weak municipal and strong county governments. Municipal revenue, debt, and expenditure figures in these states do not accurately reflect the true financial situation since the municipalities receive substantial services from the county, the costs of which are not reflected in the municipal data.

Five states or groups of states required substantial data manipulation to determine accurate financial and demographic data for primary local governments. The first group consists of seven states, primarily in the Midwest, that contain overlapping jurisdictions. The townships in these states overlap the

municipalities. In these cases, we took the county financial data, which includes township figures, and allocated it down to the municipalities on the basis of population. Our analysis indicates that townships in these states perform such limited functions that this method of allocation will introduce only very minor error.

The second group of states that presents difficulties consists of Vermont, New York, and Michigan. These states are similar to the first category, except they have villages, not townships, that overlap with municipalities. Villages in Vermont, New York, and Michigan provide only minor services, and we solved the problem exactly as we did for the Midwestern states.

Connecticut contains ten boroughs and three cities that overlap townships. In Connecticut, the township is the predominant form of municipal government. We manually eliminated these 13 overlapping entities from the database, and added their demographic and financial data to that of the associated township.

The last two categories include states with strong county and weak municipal governments. Maryland and Virginia are two such states, but, in these cases, the solution to the difficulty was relatively straightforward. In these two states, large cities are single county units, and we were able to analyze these states by county.

The last "problem" states also have strong county governments that contain significant municipal units within their counties. We encountered this situation in practically every county located in a southern state and in other counties scattered throughout the nation. To solve the problem, we searched the database to find counties in which either more than 5,000 people or more than 20 percent of the total population live in unincorporated areas. In counties that meet either of these criteria, we created a "rest of county" entity containing all population not living in incorporated areas. The allocation of county revenue, expenditure, and debt is proportionate to population in the affected areas.

Financial and Demographic Information Included

The database contains 36 variables that describe each included government. Eight of these variables were selected to compute the financial capability score; the remaining indicators are purely descriptive and allow us to characterize different

segments of the database in a variety of ways. For example, we can use this information to determine whether communities that are adversely affected by more stringent regulations are likely to be rural or smaller communities.

Initially, we examined each of the more than 100 financial and demographic indicators that the Census of Governments requires local governments to record. We needed to narrow this large field to develop a workable database. Since the major component of a bond rating is a financial capability analysis similar to the one we were undertaking, we began the narrowing process by studying the methods used by the professional bond rating services.

Standard and Poor's (S&P's), Moody's, and Fitch are the three nationally recognized bond rating services. Municipalities issuing bonds frequently ask one of these services to assign a rating to the issue. This rating serves as a measure of the issuer's ability to make payments to the bonds' holders. An S&P or Moody's bond score is therefore a measure of the financial capability of the rated government. A bond rating, however, also includes a subjective estimate of a community's willingness to pay its bondholders,⁴ a judgment not relevant to our analysis. Nonetheless, the methods of professional rating services, if not the final scores, provide valuable insight into the estimation of financial capability.

We examined S&P's and Moody's rating methods for General Obligation (G.O.) bonds, which require the issuer to pledge its full faith and credit to bond payments, and which attempt the broadest estimation of financial capability. When rating G.O. bonds, S&P gives the greatest emphasis to:

- Current or total operating deficit,
- Outstanding debt, and
- Economic base analyses.

The rating service assesses these areas by looking at fiscal factors such as current financial position and fund balance; debt measures, including trends; the community's debt service history; and a number of demographic indicators such as age, education, and wealth of the population. The worksheet included with a bond rating application requests numerous other debt, revenue, and

⁴"Pitfalls in Issuing Municipal Securities," Moody's Investors Service (January 1982), page 22.

demographic measures. Moody's asks for similar information, information about the community's relationship to the surrounding area, and information about cyclical fluctuations.

Our study of bond raters' methods served as a starting point for our own analysis. We focused on the measures that professional services have found important in determining financial capability. This approach enabled us to trim the large initial list of potential financial and demographic variables to a smaller, more manageable list. Using correlation studies, we found the few indicators that reflect information contained in numerous others. We also examined relationships between the various measures and bond ratings, and tried to confine our field to those widely used indicators that even the smaller governments record.

Our review of the data revealed several important characteristics of local government finances. In the area of debt financing, they often do not issue bonds to finance capital expenditures. We found that approximately half of all jurisdictions have no direct long-term debt. Average direct debt per capita is, therefore, only about \$200. Once overlapping jurisdictions such as school districts, special authorities, and counties are considered, however, most local governments are responsible for repaying some long-term debt; this overall debt per capita (which includes direct debt) averages about \$900. Approximately 40 percent of all long-term debt is used to finance education expenses, although this percentage varies dramatically depending on the size of the government, with smaller entities using much more of their debt to finance education.

One clear pattern in our analysis was the relationship between population size and many of the financial parameters. Larger communities tend to have higher debt and expenditures per capita and as a percentage of median household income. The pattern of their spending is also different. Smaller communities issue a much lower percentage of debt to finance utility expenditures such as water, electric, or transit services than do larger communities.

We also examined the relationship between many of the indicators and bond rating, one of the most common summary measures of financial capability. Many of the indicators show a U-shaped distribution with bond rating. For example, communities with the best bond rating (AAA or AA) have higher-than-average expenditures per capita than communities with the lowest bond ratings (BA and B1). Because the relationship between many of the indicators and bond ratings is not linear, it is difficult to test whether particular indicators are correlated with bond rating using correlation coefficients or simple regression models.

Our analysis revealed that demographic variables, such as median household income and the civilian unemployment rate, are better predictors of bond ratings than many of the debt and revenue indicators. This conclusion is the same as the one reached in a study on a much smaller database reported in the June 1986 issue of the Government Finance Review.⁵

Municipal Financial Capability Baseline

The database was used to assess the economic impacts that are likely to accrue to municipalities and their citizens from Subtitle D regulations; we estimated from the database the current or baseline financial capability of 29,017 municipalities. This section describes the objectives of the analysis to assess financial capability, the calculation of a financial capability measure, and efforts to validate the measure.

Objectives of the Financial Capability Analysis

The overall objective of the financial capability analysis is to establish the relative financial condition of municipal jurisdictions around the country. This assessment of financial condition will then be used to determine the economic impact of regulatory costs and the practicable capability of municipalities to meet these costs. In establishing a measure of financial capability, several criteria were employed to structure the analysis. They include:

- Assembling the comprehensive national data set
- Using data describing financial capability from three general areas:
 - Financial management
 - Debt burden
 - Demographic
- Producing a summary measure of impact for each jurisdiction

⁵See also "Value of Bond Ratings Questioned by a Growing Number of Studies," Wall Street Journal, September 17, 1987.

- Measuring financial capability in a relative rather than an absolute sense

Measurement of Financial Capability

To develop a measure of financial capability for municipalities, we examined a variety of financial management, municipal debt, and demographic indicators. We then selected a subset of eight indicators for assessing financial capability. The indicators are:

- Financial management
 - Total taxes as a percentage of median household income,
 - Current revenues as a percentage of current expenses,
 - Coverage ratio (funds available for debt service payments), and
 - Operating expenditures as a percentage of median household income.
- Debt
 - Net overall debt per capita (direct and overlapping debt).
- Demographic
 - Median household income,
 - Population growth from 1970 to 1980, and
 - Fraction of the population below poverty level.

The final indicators that were chosen share several characteristics: (1) they are all widely used as indicators of economic and financial health by other analysts; (2) they correlate well with other possible indicators that were not included on the final list; and (3) they are important factors in determining a community's bond rating.

To assess the baseline financial condition of municipalities, we developed a composite financial capability measure that characterizes the overall financial health of each municipality. The rating scheme works by assigning a unit score of 1 to 5 for

each indicator. A score is assigned for a municipality based on the value of its indicator relative to all other municipalities. For most indicators, a score of 5 is assigned when the municipality falls in the top 20 percent of all municipalities, 4 in the next 20 percent, and so on. For all indicators, a score of 5 indicates a strong rating, 4 above average, 3 average, 2 below average, and 1 weak.

Three of the indicators--coverage ratio, population growth, and net overall debt per capita--were handled differently from the others. For the first two indicators, most municipalities were simply rated as average, with a few categorized as either weak or strong based on the value of the indicator for that municipality. In the case of coverage ratio, for example, all municipalities whose coverage ratio exceeded 1 (approximately 85 percent of the entries) received a score of 3 (average), while the remaining municipalities were rated as weak. In the case of population growth, governments that lost more than 15 percent of their population and those that grew by more than 80 percent were both rated as weak; the remaining governments (95 percent of all entries) were rated average.

For debt per capita, we assigned communities with per capita debt of less than \$518 to the average category; we determined that it was inappropriate to score communities with very low or no debt as strong. Many communities with low or no debt may be poor risks (i.e., they cannot borrow readily) and they should not be scored strong. The remaining 40 percent of the communities receive either a score of 1 (weak) or 2 (below average).

Table IV-5 presents the range of values used to assign scores for each of the eight indicators as well as the mean and median values for these indicators.

The composite financial capability score was developed by averaging the scores for all eight indicators. The final determination of financial capability was made by examining the relative values of each government's composite score. The lowest 25 percent of the governments were rated as weak, the middle 50 percent of governments were classified as average, and the top 25 percent of governments were rated as strong.

Table IV-5

INDICATORS USED TO MEASURE BASELINE FINANCIAL CAPABILITY

Variable	Mean	Median	Strong	Above Average	Average	Below Average	Weak
Taxes as a percentage of MHI	7.3%	6.3%	<4.16	4.16-5.47	5.47-7.09	7.09-9.21	>9.21
Current revenues as a percentage of current expenditures	107%	105%	>114	108-114	103-108	98.4-103	<98.4
Coverage ratio	4	2.5	-	-	>1.00	-	<1.00
Operating expenditures as a percentage of MHI	18.5%	16.2%	<11.7	11.7-14.5	14.5-18.0	18.0-23.3	>23.3
Net overall debt per capita	\$764	\$415	-	-	<518	518-837	>837
Median household income (MHI)	\$15,209	\$14,718	>17,801	17,801-15,475	13,828-15,475	12,073-13,828	<12,073
Population growth (1980 population/1990 population)	116	109	-	-	86-180	-	<86 or >180
Population below the poverty level	13.4%	12.4%	<8.21	8.21-10.58	10.58-13.14	13.14-17.40	>17.40

Source: 105 calculations based on U.S. Census data.

Validation Efforts

Because the financial capability rating system represents a novel approach to combining census data, throughout the development of the database, we performed validity checks on the data.

Data Validation. Developing a measure of municipality specific financial capability required the compilation of detailed financial data. The generally accepted data required for such an analysis cover measures of indebtedness, fiscal responsibility, and economic vitality for a given jurisdiction. While we considered a number of ways to obtain such data for the analysis, we felt that the most cost-effective and comprehensive approach was to obtain the data directly from the U.S. Census Bureau from its general survey and survey of governmental finances.

We identified three types of problems that could lead to data inaccuracies. The first is that information was incorrectly reported to the census at the outset of the census survey. The second problem is that jurisdictions do not use uniform accounting techniques. The third problem is that the Census Bureau may have mishandled some of the data received. All of these potential problems could have occurred for some of the data elements contained in the database.

The task of identifying the magnitude of the first type of error (incorrect reporting to the census) would be enormous, essentially requiring a follow-up census that goes into greater depth than the Census Bureau. Such a validation was not practical or necessary, in our opinion. We believe that the vast majority of the data are accurate. It was carefully collected by the Census Bureau, an organization that is uniquely qualified to collect such data, and it is used extensively by such firms as Moody's, Inc., for their municipal bond rating service.

The issue of differing accounting techniques is one that we must accept as a given in conducting this analysis. Some jurisdictions maintain their books on a cash basis just as individuals do for federal income taxes. However, others use the more widely accepted accrual method, which is used by corporations. The difference between these methods is the timing of recording a cash outlay or inflow. Using a cash basis, transactions are recorded when funds change hands. Under accrual, transactions are recorded when the obligation to pay or receive funds is made. The difference between these accounting methods should be fairly small as the flow of funds into and out of public jurisdictions is relatively uniform and, therefore, cash and accrual basis accounting would produce very similar results. Our conclusion was that different accounting techniques could produce some inconsistencies in the data, but that they would not introduce a great deal of error into the analysis.

Once we were comfortable that the majority of the data would be consistent and relatively error free, we proceeded to analyze the data realizing that our most powerful tool for identifying data irregularities would be the comparison of reported figures across jurisdictions. For all of the indicator variables selected, we carefully followed a procedure of identifying and investigating the extreme outliers in a distribution. For example, as we developed the debt per capita variable we found that Valdez, Alaska, has reported debt of roughly \$1 million per person on its books, but it also has the income to cover this debt service. We surmised that a major facility for the Alaskan Pipeline was paid for with municipal bonds issued by the city. Without further investigation, we concluded that this may be a legitimate outlier. This type of outlier analysis did not typically attempt to focus on the jurisdiction's unique financial situation, such as Valdez, rather, we reviewed the other financial data for the jurisdiction to establish whether or not the observation was reasonable. We found the data to be reasonable in most cases, but, as expected with such a large data set, a limited number of peculiar entries do exist. Again, the effort required for reconciliation would be enormous and of limited value, given that 99 percent or more of the observations fell within a reasonable range.

The greatest problem that we saw with a limited number of outliers was that they created large standard deviations when calculating means. We were concerned that variables could be overweighted if the absolute magnitude of an outlier were counted in a financial score. To overcome these problems, we decided to use medians, to define the distribution of results in quintiles, and to use an ordinal, 1 through 5 scoring system that restricted the range of results.

Overall, we concluded that our data set was far superior to the alternatives. All of the alternatives involve original data collection from a limited set of jurisdictions. Such approaches could improve the quality and understanding of the data in hand, but would still have to be extrapolated to produce national estimates, thus introducing another type of error.

Results Validation. Given a reasonable data set, our next validation issue was whether or not our use of data to estimate financial capability was correct. This issue was evaluated by analyzing the results of our analysis. Our efforts in this area were limited, although we believe the results are reasonable. Our first exercise in this area was to attempt to correlate bond ratings to our scores, since bond ratings are supposed to be based on many of the same criteria that we used in the financial score. This comparison revealed that communities with low bond

ratings generally scored poorly on our system, but those with higher bond ratings did not necessarily score well on our system. This was a puzzling outcome that either meant that our scores were wrong or we did not capture all of the factors considered in setting a bond rating. We reached the conclusion that the latter case is more likely based on similar findings by other investigators (see earlier discussion of bond rating in this chapter) and anecdotal evidence that factors like the quality of bond rating presentation and apparent competence of the local officials play a major role in setting ratings.

The next step in our validation effort was to review qualitatively our scores for 30 Boston-area communities. The results of our scoring were consistent with the overall financial health of these towns.

Waste Shifts and Potential Mitigating Factors

The estimated cost to municipalities from the regulatory options assumes that the municipalities will continue to use their current landfills and then replace these landfills with similar new units once current capacity is exhausted. In reality, some landfills will be replaced by larger, regional landfills to take advantage of economies of scale, particularly in more urbanized areas. Also, the use of waste disposal alternatives such as resource recovery and recycling is becoming more common. Overall, we believe that our assumptions on landfill replacement overestimate the costs for some communities. Trends toward resource recovery, recycling, and regionalization should be strengthened by the regulation. Given the site-specific nature of these decisions, however, we were not able to quantify the extent of the overestimate. First we will discuss the effect of our assumptions and then the reasoning behind them.

Our assumption that identical, new units will replace existing units results in upper-bound estimates of compliance costs. Shifts in disposal practices are encouraged when they result in a lower net cost to the municipality. For example, despite increased transportation costs, lower disposal costs at a large, regional facility may bring about a shift. Other alternatives such as recycling or resource recovery may also be evaluated considering processing costs, residual disposal costs, transportation costs, and local markets for recovered materials or energy. When lower net cost alternatives do not exist, however, a new landfill will likely be constructed as the most economical choice. Therefore, our assumption that a new landfill will be built to replace the existing one results in costs that, for many communities, may be reduced by using regional MSW landfills or other disposal alternatives. (For smaller communities in rural areas, regional alternatives may not be readily available.)

The major reason for not evaluating waste shifts is that a comprehensive assessment of municipalities that will shift waste to larger regional landfills or other disposal alternatives would be a complex and imprecise analysis. The complexity arises from the difficulty of isolating the incremental effect of this regulation given the rapid changes in MSW disposal practices. The interaction between the regulations and the driving forces behind this change are considered in the following discussion.

The concept of waste shifts and the rationale for our assumption have been presented in terms of a pure economic choice. Clearly, landfill siting and disposal alternatives are not evaluated strictly on this criterion. Other factors that can play a significant role in these decisions include the urgency of the decision, the public's perception and opposition to a given solid waste management practice, and institutional constraints. These and similar issues must be treated as externalities in an economic analysis. They are highly variable from community to community and are difficult to quantify.

Because of issues such as those described above and the increasing attractiveness of recycling and resource recovery technologies, a shift to alternatives to land disposal is occurring in the United States. Franklin Associates, Ltd. has projected that in the year 2000, 32 million tons per year (TPY) of waste will be processed for energy recovery.⁶ This is an increase from an estimated 6.5 million TPY in 1984. Municipal waste being landfilled is projected to remain relatively constant over this period while waste generation will increase. The report acknowledges that this estimate is conservative and that others have made much higher estimates of demand for future resource recovery. It is possible that 55 million TPY may be processed for energy recovery by 2000. If this forecast holds true, energy recovery will reduce the land disposal of MSW by approximately 23 million TPY (or 18 percent).

It should be noted that ash and other residue from resource recovery plants is not included in the estimates of MSW in the Franklin Associates' report. The projected increases in resource recovery will increase the amount of those materials to be landfilled. Franklin Associates estimates that approximately 30 percent (or 2 million tons in 1984) of the waste processed for energy recovery remain to be disposed of as ash or residue.

⁶U.S. EPA Office of Solid Waste, Characterization of Municipal Solid Waste in the United States, 1960 to 2000, prepared by Franklin Associates, Ltd. (July 11, 1986; March 1988 Update).

Alternatives to land disposal other than energy recovery are also becoming increasingly common. For instance, hundreds of communities throughout the country have implemented residential recycling and yard waste composting projects. These programs are often successful because of their inherent flexibility and cost-effectiveness. However, they have historically diverted only modest amounts of municipal solid waste from the waste stream. They can affect the planning phase of a landfill or resource recovery project but cannot eliminate the need for disposal of the majority of waste being generated. For example, if a community originally planned to process or landfill 100 TPD and

then determined that a recycling/composting program could divert 10 TPD, it could downsize the facility to accommodate a smaller amount of solid waste. It could not, however, eliminate the project. Little data are available on the total amount of municipal waste that is being diverted by such programs. However, ten states have now enacted container deposit legislation that encourages recycling. Recently the State of New Jersey passed comprehensive legislation requiring recycling and banning leaves from landfills. Programs in other states (Rhode Island and Connecticut, for example) are encouraging or mandating increased recycling, and state grants to fund recycling programs are increasingly available. It would appear that recycling and yard waste composting will divert a larger percentage of municipal waste in the future.

Another alternative to land disposal of municipal waste is solid waste composting. This can be done on its own or in conjunction with refuse-derived fuel processing or sewage sludge composting. There is little recent experience with solid waste composting in the United States. The technology is, however, used successfully in Europe, the Middle East, and Asia. In the 1950s and 1960s, 17 refuse and sewage sludge composting facilities were constructed in the United States. All those facilities have since shut down because they could not compete with less expensive methods of solid waste disposal (i.e., landfills) and were unable to market the compost. Since then, an increased emphasis on landfill abatement and new marketing strategies have renewed interest in these technologies. Currently, only four solid waste composting facilities are operating in the country, but planning is under way for at least 13 new projects.

The trends discussed above will reduce at least the percentage of MSW being landfilled. Depending on how much waste generation increases, the total volume may also decline. The regulatory options would increase the cost of land disposal and, most likely, encourage the shift of waste to alternative management practices.

Another trend is toward regionalization--fewer landfills with larger service areas. The more efficient utilization of labor and equipment at larger landfills creates an economy of scale independent of regulation. In addition, the political difficulties associated with landfill siting will encourage this trend. Regulatory costs will have a greater impact on smaller landfills because of high fixed costs. By increasing the cost per ton at smaller facilities the regulations will encourage the shift toward regionalization.

To summarize, the assumption that existing landfills are replaced with new landfills of similar size provides an upper bound on the cost of the regulatory options. Current trends toward larger landfills and alternative management practices will mitigate these costs. We expect that increased regulatory costs imposed on MSWLFs will encourage these trends and it is reasonable to conclude that the actual cost of the regulatory options will be less than the costs calculated in this analysis. Because the factors that would reduce costs are complex and site specific, we are unable to quantify the extent of the overestimate.

RISK AND RESOURCE DAMAGE ANALYSIS

Introduction

The Subtitle D criteria revisions must address a diverse population of MSWLFs in a variety of environmental settings. Hundreds of factors affect the nature, extent, and severity of health and environmental impacts from these landfills. We have developed the Subtitle D Risk Model to enable us to evaluate quantitatively the adverse effects of these units on human health and resource value, and to examine the effectiveness of the regulatory options in reducing these impacts. The model couples preliminary results from EPA's Solid Waste (Municipal) Landfill Survey with a series of mathematical formulations of engineering, physicochemical, hydrologic, toxicologic, and socioeconomic processes that govern impacts, to provide a framework for evaluating regulatory options.

Our basic approach was to use the Subtitle D Risk Model to simulate risk and resource damage first in the baseline case and then under each of the regulatory options being considered. For these regulatory options, we modeled risk and resource damage in hundreds of scenarios that represent unique combinations of landfill size and design, environmental setting, and exposure distance. We then estimated the frequency with which each scenario

occurs in the nationwide population of MSWLFs, and weighted the results for each scenario to reflect its frequency of occurrence.

In the following pages we provide an overview of the Subtitle D Risk Model, and then describe how we used it to analyze the regulatory options.

The Subtitle D Risk Model

We have designed the Subtitle D Risk Model to provide (1) an analytical framework for estimating human health risk reduction and other benefits of regulatory options; (2) a direct link between estimates of regulatory benefits and costs; and (3) scenarios that contain different combinations of design, waste, environment, and response. The model builds directly on the Subtitle C Liner Location Risk and Cost Analysis Model,⁷ and has adopted many of its basic characteristics. It is a dynamic model, with time horizons of up to 400 years, although in the model runs made to support this analysis, we simulated 100 years of leachate release and up to 200 years of ground-water transport for each year's release. It models environmental fate and transport and dose-response relationships as deterministic processes, while simulating containment system failure and some hydrologic events as stochastic phenomena. The model focuses on ground water as the environmental medium of concern; releases to air and surface water are not considered. As with the cost model described earlier, some parameters can be varied over a wide range; for others, the user selects from specified "generic" values. Finally, the model resides in an integrated, computerized form that links all the supporting model components and databases.

The model includes a series of submodels that simulate pollutant release (failure/release and leachate quality submodels), fate and transport (unsaturated zone and saturated zone transport submodels), exposure, impacts (dose-response and resource damage submodels), and corrective action. These are discussed below.

Pollutant Release

The failure/release submodel uses a Monte Carlo simulation model to estimate the probability of failure (defined as release to the unsaturated zone) and the time to failure for landfills,

⁷U.S. EPA Office of Solid Waste, The Liner Location Risk and Cost Analysis Model: Phase II, Draft Report prepared by ICF, Inc. (1986).

and to estimate the quantity of leachate release. The submodel uses a "fault tree" structure; it traces each possible failure event from all possible combinations of basic events, such as liner failure and the infiltration of liquid, which could combine to cause failure. The model assumes that each of these basic events occurs at random, following specified probability distributions. Using this fault tree structure, the model predicts distributions of the year of failure and the release rates. We

used the model to simulate the performance of several combinations of containment and cover systems in eight environmental settings (four annual net infiltration rates and two depths to the water table for each infiltration rate).

Given the stochastic nature of the failure/release component and the deterministic nature of the subsequent transport, exposure, and risk modeling components, we must provide a deterministic link between the failure/release component and the "downstream" submodels. To do this we generated 250 release profiles using the Monte Carlo simulation and used a statistical clustering technique to select from one to ten typical release profiles. We used each typical profile to estimate impacts, and then weighted the results by the relative frequency with which the profile occurs in the 250 iterations. For this analysis, we selected one typical profile; this minimizes the influence of low-probability, high-consequence outcomes on the model results.

The leachate quality submodel simulates the concentrations of chemical constituents in leachate released from the landfill for up to 200 years. To account for differences in the leaching behavior of constituents, the submodel uses three different modeling approaches that simulate the concentrations of three different constituent types. To model inorganics, we developed an algorithm based on the process modeling approach described by Straub and Lynch⁸ and the semi-empirical approach described by Wigh;⁹ the algorithm calculates constituent concentrations as a function of initial concentration, cumulative infiltration, moisture capacity, an empirical parameter, and an optional constituent generation rate. For phenol (a product of waste biodegradation), we adapted a semi-empirical algorithm described by Wigh¹⁰ that calculates constituent concentration on the basis

⁸Straub, W.A. and Lynch, D.R., "Models of Landfill Leaching: Moisture Flow and Inorganic Strength," ASCE, Vol. 108, No. EE2 (1982), pp. 23-250.

⁹U.S. EPA Municipal Environmental Research Laboratory, "Comparison of Leachate Characteristics from Selected Municipal Solid Waste Test Cells," prepared by R. J. Wigh (1979).

¹⁰Ibid.

of parameters similar to those used in the inorganic algorithm. Finally, to model synthetic organic chemicals, we developed a theoretical approach that calculates concentrations on the basis of the partitioning and degradation characteristics of each constituent, initial concentration, and cumulative infiltration. The submodel applies the appropriate algorithm to calculate the concentration of each leachate constituent. The concentration is then multiplied by the annual release volume calculated by the failure/release submodel to calculate the mass flux of each constituent across the landfill/subgrade boundary.

Fate and Transport

Subsurface transport modeling addresses transport through both the unsaturated zone and the saturated zone. The Subtitle D Risk Model uses the McWhorter-Nelson Wetting Front Model to calculate the delay between the time of failure and the time that leachate reaches an underlying aquifer. The mass that breaks through the unsaturated zone then advects and disperses through the ground water. Using an adaptation of the Random-Walk Solute Transport Model developed by Prickett, Naymik, and Londquist, the model simulates ground-water concentrations over a period that covers 100 years of release and as many as 200 years of saturated zone transport for each year of release. We predict concentrations at seven downgradient distances ranging from 10 meters to 1,500 meters. These distances define the location of wells where contamination might occur. The Subtitle D Risk Model includes 11 ground-water flow scenarios that reflect variations in aquifer configuration, materials, and flow velocity. We assume that the subsurface materials are homogeneous and isotropic.

The velocity of ground water and the retardation caused by absorption of contaminants to earth materials govern the rate of constituent transport through the unsaturated and saturated zones. Retardation depends on contaminant characteristics, such as hydrophobicity and polarity, and on soil characteristics, including fraction of organic carbon, porosity, and bulk mass density. We considered degradation of chemicals where data are adequate to develop rates, and this factor can have a major effect on concentration profiles.

Exposure

The ground-water concentrations of chemical constituents released from landfills can cause human exposure through drinking water. We assumed that all exposed individuals weigh 70 kilograms and drink two liters of water per day. We calculated the lifetime dose as the running 70-year average over an individual's lifetime.

Impacts: Human Health Risk

To estimate risks for carcinogenic effects we used the dose-response functions developed by EPA's Carcinogen Assessment Group (CAG) (i.e., the upper 95 percent confidence interval on carcinogenic potency). For systemic effects, we used the Weibull equation with a threshold to predict a probability of effect, rather than using the traditional direct comparison to some reference dose.

We report risks as the average, most exposed individual risk (i.e., the average lifetime risk to the most exposed individual over the modeling period). By using data on the size of the population drinking from wells, we also predicted population risks.

Impacts: Resource Damage

Resource damage (RD) is an alternate measure of impacts associated with releases from Subtitle D landfills. It is based on the premise that ground water is a valuable resource, and that there is a loss in resource value if the water is rendered unfit for human consumption. We assigned a monetary value to the drinking water supply by assuming that it is no more valuable than the least expensive substitute. Thus, we estimated resource damage as the cost to provide alternative drinking water supplies to people whose wells are contaminated by releases from landfills.

Human health risk and resource damage are mutually exclusive measures of impacts. The former quantifies the potential risks from the ingestion of contaminated ground water, while the latter estimates the costs of replacing the contaminated water supplies. These impacts obviously could not occur simultaneously, because exposure would end when the water supply is replaced, and therefore one cannot add risk and resource damage to derive an overall estimate of impacts. Resource damage does provide us with an alternate measure of impacts, one that (unlike human health risk) provides some measure of benefits even if no people currently live near the landfill. Resource damage is a particularly important measure of benefits in the current analysis, where over half of the units pose no risk because there are no nearby wells.

We used the costs of replacing water supplies only as a way to place a monetary value on ground water; these replacement costs should not be viewed as corrective action costs. We assumed that ground water is unsuitable for human consumption

when pollutant levels exceed regulatory limits (MCLs) or taste and odor thresholds, and these levels do not necessarily correspond to those that trigger corrective action.

In our approach, RD depends on the area of the plume, the time it first appears, the drinking-water well density, the source of the alternative water supply, and whether or not the ground water is currently used. The Subtitle D Risk Model calculates the maximum plume area based on the maximum plume width at each of the seven well distances. The maximum plume area multiplied by well density and number of users per well determines the total population affected and sets the size of the replacement water supply system. The well density used in the analysis, one well per 80 acres, and the average population served per well (128) are the mean values reported in the Subtitle D facility survey for those facilities with private or public wells. To estimate water supply system size, we assumed that each person consumes 65 gallons of water per day (total use).

The replacement scenarios offer a choice between replacing contaminated ground water with nearby ground water, nearby surface water, distant ground water, or distant surface water. The two distances chosen to define the scenarios are one mile and 10.5 miles. Each scenario includes the costs to acquire, transport, treat (surface water only), and distribute water to the user population. For this analysis we used the "nearby ground-water" replacement scenario, which we believe is the most typical.

The last parameter determining resource damage is the use scenario. We estimated RD under two scenarios: use value and option value. Use value represents the RD for the population that is currently using the ground water for drinking water, whereas option value represents the RD for the population that is not currently using the ground water for drinking water but may wish to do so in the future. For use value, the RD equals the present value of the cost to replace the ground water. For option value, the RD measure incorporates the probabilistic nature of future use; replacement costs are multiplied by an estimated probability of use in each time period. These products are summed in present value terms.

Corrective Action

The Subtitle D Risk Model also simulates the effects of various corrective measures on contaminant concentrations and, consequently, on risk and resource damage. Corrective actions

are triggered when contaminant concentrations exceed specific thresholds (analytical detection limits or, for those pollutants regulated under the Safe Drinking Water Act, maximum contaminant levels or MCLs) at a downgradient monitoring well. The model employs decision criteria to select an appropriate corrective action technology (CAT) (e.g., capping, excavation, slurry walls, extraction wells, or drains) on the basis of landfill size, hydrogeology, and the distance the plume has traveled. The model estimates the effects of the selected corrective action on down-gradient well concentration profiles and recomputes risk and resource damage. For this analysis we limited the model to the use of recovery wells as the appropriate CAT, since recovery wells were generally found to be the least-cost CAT.

Model Inputs and Supporting Analyses

The model runs used to analyze the effectiveness of the regulatory options cover a variety of design and environmental scenarios. We explain below our choice of model inputs, some of the supporting work on which the analysis is based, and our methods for assigning frequency weights to each set of factors.

Facility Size

We modeled three landfill sizes: 10 TPD, 175 TPD, and 750 TPD. Each category is characterized by the total volume of waste placed in the landfill, the number of phases used to dispose the waste (the common practice is to sequentially fill and then close individual sections of the landfill), and the dimensions of the landfill at capacity (surface area, depth, height). The waste volumes and dimensions for each capacity category were estimated by the design and cost model described earlier in the chapter. The number of phases in the risk analysis are 2, 5, and 10 for the 10-TPD, 175-TPD, and 750-TPD landfills, respectively.

We used EPA's MSWLF survey to estimate the frequency with which each landfill size category occurs nationwide. We included landfills with capacities of up to 30 TPD in our 10-TPD category, 30 to 500 TPD landfills are in the 175-TPD category, and those with larger capacities are modeled as 750-TPD units. Using this approach, we modeled 61.5 percent of the landfills as 10 TPD, 33.1 percent as 175 TPD, and 5.5 percent as 750 TPD. We assumed that facility size is independent of hydrogeologic and exposure attributes.

Facility Design and Operation

For the risk and resource damage analysis, we assumed that all landfills are new. For the baseline, we modeled a landfill that operates for 20 years and then closes with a vegetative cover. There is no post-closure care period, no ground-water monitoring, and no corrective action. To simulate the impact of the regulatory options, we assumed that a new landfill is constructed at the same site and is designed and operated throughout its lifetime (20 years) and the post-closure care period. The post-closure care period modeled simulates the two-phased approach described in the Proposal. For 30 years after the unit closes, the cover components are maintained and, if necessary, replaced. Ground-water monitoring continues after the end of the first 30 years; the risk model simulates a total of 100 years of leachate release, so the modeled monitoring period is 100 years as well (20 years operating life + 30 years phase one post-closure care + 50 years of phase two post-closure care).

We did not model the effectiveness of the regulatory alternatives at existing units, where some of the waste is already in place; this would require us to model pollutant release and transport at a unit that has mixed designs (e.g., some unlined cells and some lined cells), which is currently beyond the capability of the Subtitle D Risk Model. This also limited our ability to model corrective action costs for existing MSWLFs.

Unlike the cost analysis, the risk analysis did not take account of states with existing containment system requirements that would satisfy the Proposal's performance standard. In 22 states, the incremental risk reduction or RD reduction attributable to these systems should not be credited to this rulemaking. To the extent that we have not accounted for existing state containment system requirements, we overestimate risk reduction somewhat under the Proposal.

Our approach for simulating corrective action is described in the next section. In the rest of this section, we discuss how we analyzed facility design under each regulatory option.

Proposal. Under the Proposal, landfills are required to meet the design goal. In our modeling, we assumed that the design goal would be set at 10^{-5} at the compliance point. As modeled this was interpreted to mean that constituent concentrations would not exceed levels that would impose a 300-year

average most exposed individual lifetime cancer risk of 10^{-5} .¹¹ The 10-meter point of compliance is at the unit boundary, while the alternative compliance point is 150 meters from the waste boundary. In our modeling, we simulated risk at the unit boundary using the Subtitle D Risk Model 10-meter well distance. To analyze the 150-meter compliance point, we interpolated risk results from the 60-meter and 200-meter wells.

To analyze the Proposal, we simulated risk using three different designs: unlined with vegetative cover, unlined with synthetic cover, and synthetic-lined with synthetic cover plus an LCS; each of these designs is described earlier in this chapter.

We assigned each size/infiltration/flow field scenario to the least stringent design capable of meeting the design goal. We assumed that all scenarios with 300-year average individual risk exceeding 10^{-5} at the compliance point would, at a minimum, install a synthetic cover at closure. If 300-year average individual risk at the compliance point was reduced to 10^{-5} or less by installing the cover, we assumed that this design would be sufficient to meet the design goal. For landfills that could not meet the performance standard with a synthetic cover, we assumed that both a synthetic liner (with an LCS) and a synthetic cover would be necessary. As described earlier, if the synthetic/synthetic design was still insufficient, corrective action would be triggered.

Alternative 1. Under Alternative 1, all landfills are required to have a composite/synthetic liner, two leachate collection systems, a composite cover, and post-closure care. We assumed that the cover is maintained and replaced if necessary until the end of the first 30 years of post-closure care, but that ground-water monitoring is conducted throughout the entire period (a total of 80 years after closure). To analyze the effectiveness of Alternative 1, we simulated risk and resource damage for each size/setting/flow field/well distance scenario under this design. If the 300-year average individual risk at the unit boundary was above 10^{-5} with the containment systems in place, corrective action would be triggered.

¹¹Using the 300-year average individual lifetime risk may underestimate the number of scenarios in which the 10^{-5} threshold is exceeded and, therefore, underestimate both the fraction of units assigned the more expensive designs and the risk reduction provided by the Proposal. At some time during the averaging period, constituent concentrations may exceed levels leading to a risk of 10^{-5} ; to the extent that the design goal is set at a maximum lifetime or an "instantaneous" threshold, use of the average will smooth out these peaks.

Alternative 2. Alternative 2 imposes both design and performance standards on landfills. The only explicit design requirement is for leachate collection systems at landfills that generate more than one foot of leachate during their active life. Performance standards relating to time of travel to the uppermost aquifer and to infiltration of water through the cover may be met with a number of different designs. As discussed previously, for the cost analysis, we used some simplifying assumptions to identify seven distinct designs that are likely to emerge in response to Alternative 2.

Given time constraints, seven designs were too many to simulate for the benefits analysis. We thus reduced the number of designs to four: unlined with a vegetative cover, clay-lined with a vegetative cover, unlined with a synthetic cover, and synthetic-lined with a synthetic cover. We used the synthetic/synthetic design as a proxy for two of the designs that we did not model rigorously (unlined, LCS, synthetic cover; and synthetic-lined, LCS, vegetative cover). Each of these designs is applicable to about 8 percent of all landfills. Both require an LCS combined with either a synthetic liner or a synthetic cover, and of the four designs that we modeled, the synthetic/synthetic (with LCS) design is most similar in terms of leachate release. We used the baseline design (i.e., unlined, no LCS, vegetative cover) as a proxy for the design that requires no liner, an LCS, and a vegetative cover. This design occurs quite infrequently (about 3 percent of the landfills). We analyzed corrective action as being triggered when the 300-year average individual risk at the unit boundary exceeds 10^{-5} with these designs in place. This occurred only for landfills with the synthetic/synthetic design.

Alternative 3. Under Alternative 3, landfills are allowed to operate with vegetative covers and no liners, but must perform corrective action if constituents exceed 10^{-5} risk levels at the unit boundary. For landfills that did not trigger corrective action in the baseline, we assumed that risk and resource damage was equal to baseline levels. Our approach for analyzing the effectiveness of corrective action is discussed in the next section.

Corrective Action

As discussed previously, the Subtitle D Risk Model simulates the costs and effectiveness of a corrective action program that begins when contaminant levels at a compliance point exceed trigger levels such as MCLs or analytical detection limits. However, the corrective action requirements under the Proposal as

well as all of the regulatory alternatives are different from the type of program simulated by the model. Given time constraints, we were unable to rigorously analyze the corrective action requirements in the current rulemaking. Below, we describe how we use the results of the Subtitle D Risk Model's corrective action submodel to approximate the costs and effectiveness of the proposed corrective action program simulated for all the regulatory options.

New Units. For the Proposal, we assumed that all model scenarios that met the design goal (300-year average individual risk of 10^{-5} or less at the compliance point) with the appropriate designs in place would not trigger corrective action. Scenarios that were assigned to the unlined/vegetative or unlined/synthetic designs, then, did not trigger corrective action. (If risk had been higher than 10^{-5} , they would have been assigned to a more stringent design. We recognize that there are situations in which landfills will not be properly designed and the performance standard will not be met, triggering corrective action. Accounting for these types of situations is, however, beyond the scope of this analysis.) If scenarios with the synthetic/synthetic design (the most stringent of the three designs) still had 300-year average individual risks exceeding 10^{-5} , we assumed that corrective action would be triggered. These assignments are shown earlier in this chapter. We assumed that these landfills would not implement an even more stringent design to meet the design goal. The rationale for this assumption is that past modeling has shown that for scenarios characterized by relatively high risk, more stringent containment generally has only marginal benefits over a synthetic/synthetic design.

For the synthetic/synthetic design scenarios that triggered corrective action, we based our analysis of corrective action costs and benefits on previous Subtitle D Risk Model runs. These previous runs had been used to simulate the costs and benefits of ground-water recovery wells at landfills with vegetative covers and no liners, for each size/infiltration/flow field/well distance scenario. We assumed that corrective action implemented in conjunction with a synthetic/synthetic design would provide the same percentage reduction in risk and resource damage as it did in these previous runs. To determine the present value of the corrective action costs, we discounted the costs simulated in the previous runs to account for the delay in releases that would be provided by the containment systems.

We applied a similar methodology to analyze corrective action costs and benefits under each regulatory alternative. We assumed that corrective action would be triggered only if

the 300-year average individual risk exceeded 10^{-5} at the unit boundary (i.e., the 10-meter well), and extrapolated costs and benefits from the previous runs described above. For Alternative 3, which requires only corrective action, we did not adjust the previous runs. For the Proposal and all alternatives, the POC for triggering corrective action is also the POC for cleanup.

Using this approach, we found that corrective action did not reduce risk to 10^{-5} for some scenarios, and in other scenarios reduced contaminant levels below the 10^{-5} risk level. One reason for this is that the model runs that we used for the analysis had different corrective action target levels (MCLs and analytical detection limits), and it is likely that the duration of the recovery well technology would have been different had it been aimed at reducing contaminant concentrations to a 10^{-5} risk level.

Existing Units. Corrective action at existing units was modeled differently than for new units. We used a different approach for two reasons. First, we assumed that states will decide to react to existing contamination more passively than they will for future contamination. This is primarily because of practical constraints (money, technical resources) on addressing existing releases. Second, modeling the performance of existing units with starting dates ranging from 1986 back to the late 1800s is inherently difficult.

Existing units that trigger corrective action were modeled as having two possible responses. For those with the most extensive contamination (i.e., the contaminants exceeded the 10^{-5} risk threshold at the 600-meter well distance), active cleanup was required. The remaining landfills were not assigned cleanup costs, but were instead assigned costs to replace the contaminated ground-water supply, assuming flexibility in the timing of the cleanup. For these remaining landfills, if resource damage is triggered in the Risk Model, then the owner/operator must replace the ground-water supply at that time. If wells exist downgradient, we applied replacement costs using the same algorithms applied in the use value approach to measuring resource damage. Those without wells pay replacement costs in the future, based on the same approach used to estimate option value (i.e., the costs are computed on an expected value basis to account for future use of the water).

The difficulty with modeling corrective action at existing facilities is the range of ages of landfills. To account for the different ages, we categorized landfills into age categories and calculated the incidence and costs for corrective action given several discrete estimates for past life.

Because all existing units are assumed to have similar designs for the benefits analysis, we assumed that existing corrective action costs would be the same across all the regulatory options. The addition of more elaborate cover systems at closure would probably reduce corrective action costs compared to those presented here, but time and model constraints prevented our analyzing this in any detail. This will tend to overestimate corrective action costs somewhat.

Environmental Settings

The timing of pollutant release and the rate at which pollutants enter an aquifer are influenced significantly by climate and hydrogeology. Two important parameters are net infiltration (precipitation minus evapotranspiration) and ground-water table depth. Net infiltration determines the amount of water that can enter a landfill as a result of precipitation. Ground-water table depth is important for two reasons. First, the depth to ground water determines the thickness of the unsaturated zone, an area in which significant pollutant retardation and degradation may occur. Second, for facilities that are seasonally inundated with ground water, the inundation depth determines the rate at which ground water can flow through the waste.

We used these two parameters to define eight environmental settings for the failure/release submodel runs. The settings, shown in Table IV-6, consist of four annual net infiltration regimes (0.25-inch, 1-inch, 10-inch, and 20-inch) and two categories of ground-water table depths for each infiltration region (deep and shallow). To determine the mean depth to ground water and the average annual ground-water fluctuations, we performed a statistical analysis of U.S. Geological Survey (USGS) data for each infiltration category. We chose approximate 50th and 90th percentile water table depths to represent the shallow and deep conditions, respectively.

Table IV-6

FAILURE/RELEASE SUBMODEL ENVIRONMENTAL SETTINGS

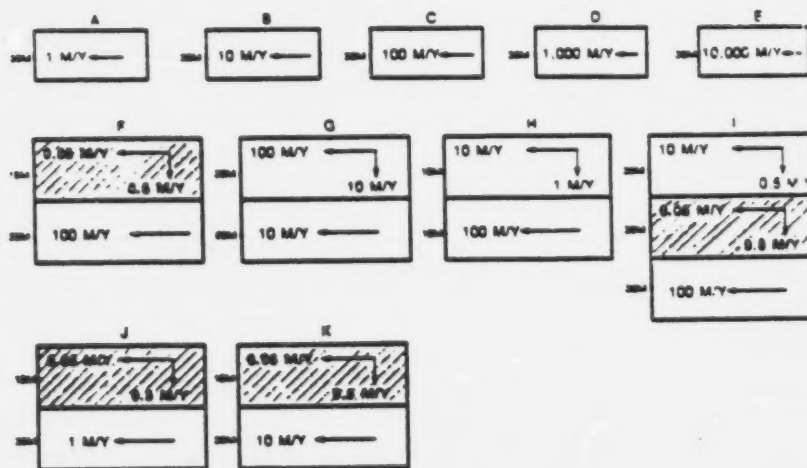
Annual Net Infiltration (inches)	Mean Water Table Depth/ Average Annual Fluctuation (feet)
0.25	Deep: 200/1.7
0.25	Shallow: 17/1.7
1.0	Deep: 129/1.8
1.0	Shallow: 20/1.8
10.0	Deep: 47/2.4
10.0	Shallow: 15/2.4
20.0	Deep: 52/2.8
20.0	Shallow: 20/2.8

For all eight settings, we assumed that the subgrade underlying the waste has a saturated hydraulic conductivity of 10^{-4} centimeters per second (cm/sec). This subgrade is sufficiently permeable to allow leachate to be released at the same rate at which it is formed. For most net infiltration regions, the subgrade conductivity would have to be very low (i.e., 10^{-7} cm/sec or less) before it would limit leachate release rates. According to EPA's MSWLF survey, few landfills have subgrade conductivities this low.

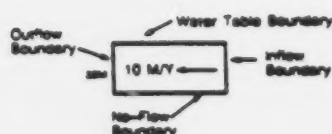
To model the transport of constituents in the saturated zone, we developed 11 generic ground-water flow fields to represent the range of hydrogeologic conditions in the United States. We based the flow fields on data collected from ground-water supply reports for each of the USGS ground-water regions. The flow fields, shown in Figure IV-6, vary in terms of aquifer configuration, materials, and flow velocity. Five of the flow fields (A, B, C, D, and E) are single-layer aquifer systems, two (G and H) contain two adjacent aquifers, three (F, J, and K) consist of an aquifer overlaid with a nonaquifer, and one (I) contains two aquifers separated by a nonaquifer.

Figure IV-6

**Eleven Generic Ground-Water Flow Fields
Used in Saturated Zone Transport Modeling**



EXPLANATION



Average Linear Groundwater Velocity Vectors
(Meters/Year) Through Each Layer of Saturated
Material with Constant Thickness (Meters)
Cross-Hatch Lines Indicate Layer is Non-Aquifer

To estimate the frequency with which landfills are located in each of these environmental settings, we determined the latitudes and longitudes of over 700 landfills from the facility survey and a separate mapping effort. We used precipitation and other climatic data collected at weather stations near each landfill to assign the site to a net infiltration region. We also determined the likely DRASTIC setting¹² for each landfill, and used ground-water data characterizing these settings to assign sites to ground-water table depths and flow fields. Flow fields I and J were virtually absent from our set of characterized facilities, and therefore we did not model them.

We assigned each environmental setting (i.e., combination of net infiltration, depth to water table, and flow field) a unique frequency weight. These weights were used to scale the risk model weighted corrective action costs described earlier in this chapter. We assumed that the environmental setting is independent of facility size and exposure characteristics.

Leachate Characterization

We simulated one representative leachate characterized by a specified set of constituents. This typical leachate is intended to represent leachates generated from the co-disposal of municipal solid waste, nonhazardous industrial waste, household hazardous waste, and a small quantity generator of hazardous waste. Because leachates for similar landfills vary significantly in composition, we determined characteristic constituents (and their initial concentrations) by analyzing leachate composition data covering 212 chemical constituents at 44 operating MSWLFs.

The landfills included in this analysis were the OSW case study landfills, New Jersey landfills that discharge leachates under National Pollutant Discharge Elimination System (NPDES) permits, and landfills surveyed for the presence of organic chemicals in Wisconsin and Minnesota. We determined representative concentrations of the constituents based on the median reported concentration; mean concentrations were not used in order to reduce the effect of single, anomalous values. In determining median concentrations, we used the detection limit as default concentrations for situations in which a constituent was tested for but not detected. We calculated median concentrations

¹²U.S. EPA, DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings, EPA/600/2-85/018 (1985).

for 96 of the 212 constituents that had been analyzed at the 44 facilities; we did not calculate median concentrations for 116 constituents because they either had not been detected at any facility or had been tested for at only one facility.

From the final list of 96 constituents observed in MSW leachate, we selected eight constituents of concern (COC) for risk modeling. Our approach for selecting COC was designed to identify the constituents with the highest potential for causing human health risk or resource damage on the basis of the following considerations:

- Observed concentrations in MSWLF leachate,
- Toxicity to humans,
- Regulatory limits under the Safe Drinking Water Act,
- Taste and odor thresholds, and
- Mobility and persistence in the subsurface environment.

To select the COC, we began with the medians of the observed constituent concentrations in leachate. Borrowing from the modeling efforts of the Organic Toxicity Characteristic Rule (FR 51:21648), we divided these by a conservative (90th percentile lowest) dilution/attenuation factor of 10 to estimate concentrations in ground water at a well 500 feet from the landfill. We compared these ground-water concentrations with risk-based threshold values for each constituent. The human health risk threshold corresponds to a cancer risk of 10^{-6} for carcinogens or a reference dose for noncarcinogens. The resource damage threshold is the lowest of a Safe Drinking Water Act MCL (existing or proposed), a taste and odor threshold (from the Liner Location Model database), or a threshold for agricultural use (EPA's Water Quality Criteria).

To make the comparison, we divided the ground-water concentration by both the human health risk and resource damage threshold for each constituent. We eliminated from further consideration all ratios below 1, leaving 22 constituents as candidates for risk modeling. We selected the final eight COC from this list, giving primary consideration to the magnitude of the ratio, but also considering secondary factors such as mobility and persistence.

Table IV-7 presents the eight COC, the effect for each, and the ratio of its concentration in ground water to its threshold concentration.

Table IV-7
CONSTITUENTS OF CONCERN

<u>Constituent</u>	<u>Ratio</u>	<u>Criterion (effect)</u>
Vinyl chloride ¹	658	Human health risk (cancer)
Arsenic	579	Human health risk (cancer)
Iron	22	Resource damage (taste and odor)
1,1,2,2-Tetrachloroethane	11	Human health risk (cancer)
Dichloromethane	9	Human health risk (cancer)
Carbon tetrachloride	4	Human health risk (cancer)
Antimony	3	Human health risk (systemic)
Phenol	2	Resource damage (taste and odor)

¹Because tetrachloroethene, trichloroethene, and 1,2-dichloroethene degrade into vinyl chloride, we took the stoichiometric equivalents of the three constituents and converted them to concentrations of vinyl chloride. Because vinyl chloride is more toxic than the other three chloroethenes, this approach is conservative.

We also calculated the 90th percentile concentration of each constituent of concern; these are presented along with the medians in Table IV-8.

Table IV-8
MEDIAN AND 90TH PERCENTILE CONCENTRATIONS
FOR CONSTITUENTS OF CONCERN
(milligrams/liter)

<u>Constituent</u>	<u>Median</u>	<u>90th Percentile</u>
Vinyl chloride	0.10	1.28
Arsenic	0.01	0.044
Iron	66.2	380
1,1,2,2-Tetrachloroethane	0.02	0.212
Dichloromethane	0.23	2.56
Carbon tetrachloride	0.01	0.163
Antimony	0.47	1.05
Phenol	0.26	5.58

We do not rigorously simulate impacts from the 90th percentiles, but we do use them as a basis for estimating an approximate upper bound on risk. The results are presented in Chapter V.

Impacts

Of the constituents of concern selected for modeling human health risk, five are carcinogens and one is a noncarcinogen. Our approach for estimating risks for carcinogenic effects is consistent with EPA's cancer risk assessment guidelines and uses a function that is linear at low doses, with no threshold. We used the carcinogenic potencies developed by EPA's Carcinogen Assessment Group (i.e., 95 percent upper-bound slopes based on the linearized multistage model). The potencies are shown in Table IV-9.

Table IV-9	
CARCINOGENIC POTENCIES FOR CONSTITUENTS OF CONCERN	
<u>Constituent</u>	<u>Potency (mg/kg-day)⁻¹</u>
Arsenic	15
Carbon tetrachloride	0.13
Dichloromethane	0.0075
1,1,2,2-Tetrachloroethane	0.2
Vinyl chloride	2.3

For noncarcinogenic effects, we used the Weibull equation with a threshold to predict a probability of effect. Below the threshold, risk equals zero. At doses above the threshold, risk depends on the dose, the constituent-specific threshold, and the dose-response parameter. Antimony is the only systemic toxicant selected for risk modeling; the threshold and dose-response parameter used for antimony are 4.1×10^{-5} (milligrams per kilogram-day [mg/kg-day]) and 1.4×10^5 (mg/kg-day)⁻², respectively. Predicted antimony concentrations never exceed the threshold in our model runs, so all the risk predicted is cancer risk.

Exposure Distance and Populations

We selected seven well distances for modeling risk: 10 meters, 60 meters, 200 meters, 400 meters, 600 meters, 1,000 meters, and 1,500 meters. We used data from EPA's MSWLF survey to develop a distribution of distance from the landfill to the closest well at each site, and used this well distance distribution to develop frequency weights for each of the seven wells (Table IV-10). Because risk usually decreases with increasing distance from the landfill, we used this distribution (distance to the closest well) to estimate risk to the maximally

exposed individual (MEI). Note that only 46 percent of the landfills reported that they currently have downgradient wells within one mile. Thus, at the other 54 percent of the facilities, there would be no human health risk from drinking contaminated ground water within one mile of the unit.

Table IV-10		
DISTANCE TO NEAREST PUBLIC OR PRIVATE WELL		
(meters)		
<u>Model Well Distance</u>	<u>Actual Well Distance Range</u>	<u>Percentage of Landfills</u>
10	0-35	2.4%
60	35-130	4.4
200	130-300	6.0
400	300-500	12.7
600	500-800	5.0
1,000	800-1,250	9.8
1,500	1,250-1,600	5.3
None	Within 1 mile	54.4
		100.0%
Source: EPA Municipal Landfill Survey.		

Under the Proposal, states may establish an alternative boundary beyond the waste management unit boundary as the compliance point for a new unit. This alternative boundary cannot go beyond 150 meters. For this analysis, we assumed that an alternative compliance point for all MSWLFs is set 150 meters from the waste boundary. As discussed earlier, we did not model risk at the 150-meter well; we determined risk at this distance by interpolating from the results at the 60-meter and 200-meter wells. We assumed that no exposure would occur inside this point. For our analysis of the alternative compliance point, we assumed that all wells located at 10 or 60 meters would instead be located at 150 meters. Therefore, we deleted the 10- and 60-meter wells as exposure points under the alternative compliance point, and used the sum of their frequency weights (6.8 percent) to derive the weight for the 150-meter well. Because we did not delete the closer wells (which generally have the highest MEI risk) from the well distribution when we simulated baseline risk, this assumption leads us to slightly overestimate the effectiveness of the Proposal at the alternative compliance point. Nevertheless, this assumption was necessary to avoid simulating two different baselines.

To calculate population risk (number of predicted cases), we used survey data on distance to all wells within one mile downgradient and the number of people served at each well. Across private and public wells, the mean well density for landfills with downgradient wells was about one well per 80 acres, with private wells occurring far more frequently. The mean population served per well was about 128, but this mean is strongly influenced by relatively infrequent but large populations serviced by public wells. These numbers indicate a density of about 1.6 well-using people per acre of downgradient land. We calculated the land area associated with each exposure well and multiplied the area by this population density to estimate the size of the exposed population for each well at sites with wells.

V. RESULTS

In this chapter, we present the results of the cost analysis, followed by the results of the analyses of economic impact, regulatory flexibility, risk, and resource damage.

COSTS

We begin the cost analysis by examining the current expenditures of MSWLF owner/operators. These expenditures provide a benchmark against which to compare changes in operating costs due to regulation. In the analysis, we use the Design and Cost Model to estimate baseline costs so assumptions are consistent across the baseline and the four regulatory options. We then apply the cost methodology described in Chapter IV to estimate the incremental costs of compliance with the Proposal and with the three regulatory alternatives. In the first section of the cost analysis, however, we compare this analytical baseline estimated using the Design and Cost Model with survey information on reported annual expenditures.

In subsequent sections of the cost analysis, we report costs as incremental costs above the analytical baseline. We examine the costs in three different ways: the costs for new landfills assuming a 20-year life as described in Chapter IV, the costs for existing units where the remaining life is variable, and the combined costs incorporating both new and existing unit costs. We also discuss costs dependent on risk model results (i.e., phase two ground-water monitoring costs assumed for the Proposal and corrective action).

Because the risk analysis is limited to new units, we will use new-unit costs to compare cost-effectiveness among the various options in Chapter VI. For the economic impact analysis, however, we focus on the combined cost as a more complete measure of incremental costs attributable to the regulation.

Baseline

The costs presented in this chapter are all reported as incremental costs: the difference in cost incurred because of the imposition of new regulatory requirements. In order to estimate the baseline from which to measure the difference, we used the Design and Cost Model described in Chapter IV. Throughout the RIA we refer to this as the analytical baseline.

As a validation exercise, we reviewed information from the facility survey reporting landfills' actual annual operating expenditures. Though these costs may not include amortization expenses for capital equipment, we adjusted the reported costs to costs per ton and plotted them against waste quantity received in tons per day. Figure V-1 shows the resulting plot for the landfills that provided the estimates. Note that waste quantity is shown on a logarithmic scale. The numbers on the plot indicate the number of responses at each point from 1 through 9. "A" stands for 10, "B" 11, and so on.

The figure emphasizes the clustering of landfills with small quantities accepted. The median cost per ton for all MSWLFs surveyed is \$11; this compares with a baseline median cost per ton of \$35 estimated for all MSWLFs using the Cost Model. As size increases, reported annual operating costs per ton decline. For reference, we fit a regression line to the reported data and included it on the figure. In addition, we also plotted the Cost Model analytical baseline. While it lies above the regression line, especially for smaller units, it is within the range of reported estimates. Because the reported costs may not include equipment and other amortized capital expenses, we believe that the analytical baseline is a reasonable baseline for the analysis. In several subsequent sections of the chapter we will report incremental costs as a percentage increase above current annual operating costs; this refers to the increase above the reported costs, from the survey, plotted on this figure.

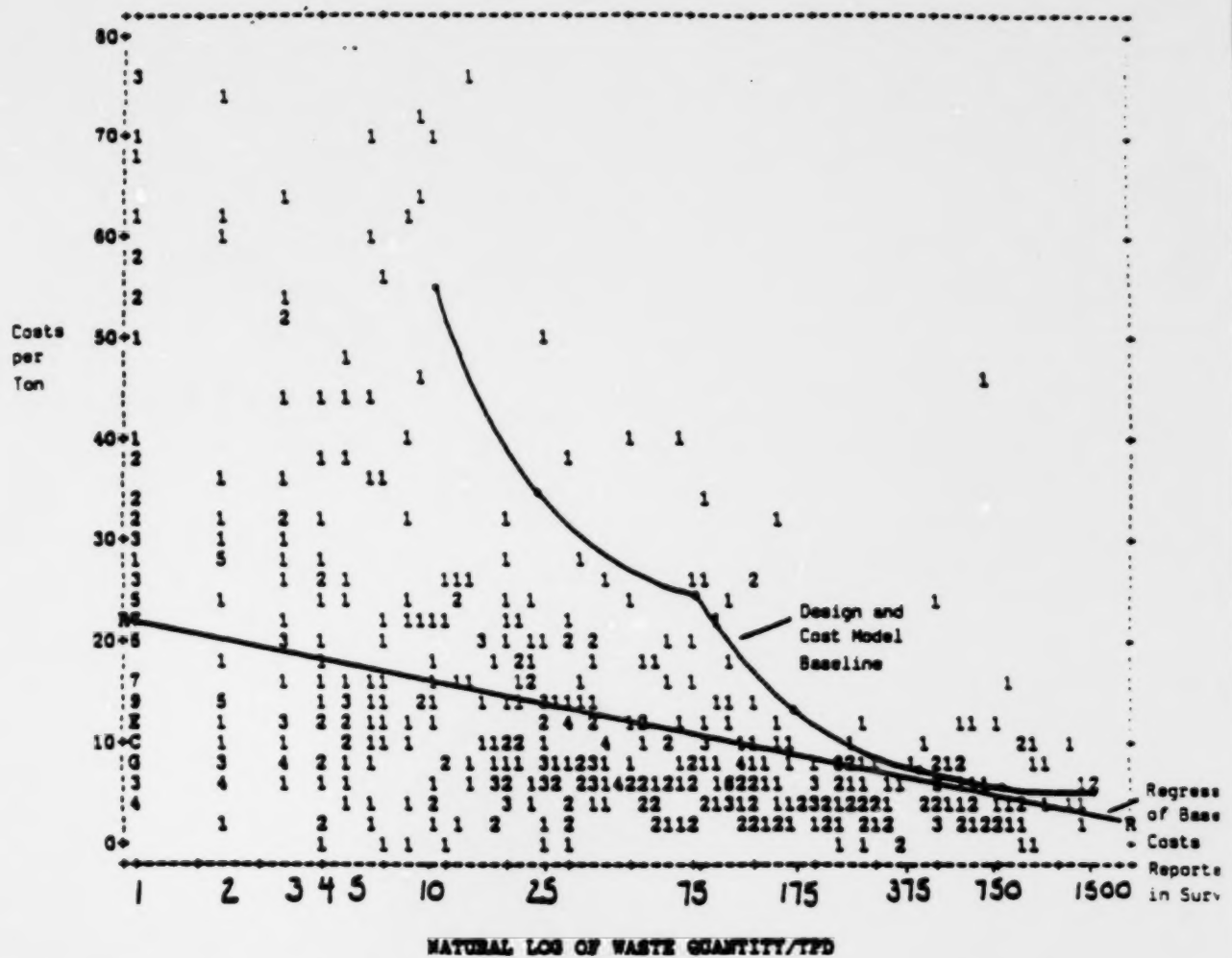
Proposed Rule: 10-Meter and 150-Meter Points of Compliance

The Proposal imposes different costs on MSWLFs depending on the design necessary to comply with the state-specified design goal at the appropriate point of compliance (POC). We will present the analysis of the costs at both POCs simultaneously because all the unit cost information is the same for each scenario; the difference comes in the assignment of designs to actual landfills. First we discuss unit cost estimates for new and existing landfills and then aggregate them to calculate national cost estimates for both POCs.

The unit costs presented in this chapter assume full compliance with the regulatory option and do not take account of the states in which some of these requirements are already in place. These exceptions are reflected in the computation of combined costs and aggregate national costs. As described in Chapter IV, for each regulatory option we excluded costs for ground-water monitoring wells at 2,702 landfills in states that EPA identified

Figure V-1

Baseline Costs: Modeled Values Versus Reported Values



370 cases plotted. Regression statistics of CPT on LNWD:
Correlation = .40926 R Squared

as having roughly equivalent programs. Also, we excluded containment system costs (when these systems would be required under the Proposal) for landfills in states with equivalent programs. As reported in Chapter IV, EPA identified 22 states (containing 3,657 landfills) with equivalent programs.

New Units .

The costs for new units assume that construction begins immediately and that the units have a 20-year operating life. In the economic analysis and for the combined costs, the starting date is delayed until the expected life of the existing unit is exhausted. Table V-1 presents the annualized incremental costs per ton for each of the design options we modeled for the Proposal. As described in Chapter IV, the more stringent designs are assigned to units for which less elaborate designs do not reduce risk below 10^{-5} . The largest incremental cost is imposed by the synthetic cover, synthetic liner, and leachate collection system installed on the high-risk units: the incremental costs per ton are three to eight times higher for the synthetic/synthetic design than for the unlined/vegetative design.

Table V-1			
INCREMENTAL COSTS FOR NEW LANDFILLS			
Proposed Rule			
Cost per Ton			
Size (TPD)	Unlined/ Vegetative Cover	Unlined/ Synthetic Cover	Synthetic Liner/ Synthetic Cover
10	\$10.01	\$14.18	\$31.14
25	6.06	9.48	23.19
75	3.41	5.73	14.75
175	2.44	4.29	11.41
375	1.63	3.05	8.46
750	0.97	1.98	5.78
1,500	0.75	1.86	6.10

The estimates demonstrate the positive returns to scale for MSWLF design and operation over most of the size range. At the largest sized unit, the economies of scale break down for the designs with synthetic liners. The incremental cost for this design is dominated by a containment system that is keyed to the area of the unit. Since the depth of these model-sized units is

fixed, the units get higher and wider as the tonnage increases. At larger sizes, however, the height approaches a practical limit. At that point, costs that are related to area increase rapidly with increases in tonnage. As a result, costs per ton may level out or even increase. In general, if tonnage increases and the area increases by less than the same proportion, the costs per ton of waste will decline. If area increases by the same or greater proportion, the unit costs will increase.

The costs for all designs include the general facility standards described in Chapter IV and the cost to assess compliance with the design goal. For the unlined/vegetative design, these costs account for about 36 percent of the incremental cost at the 10TPD landfills and 61 percent of the cost at the 1,500-TPD units. These costs include gas monitoring, run-on and run-off controls, and higher engineering and quality assurance (QA) fees on excavation and design. The remainder (64 percent for the 10-TPD units and 39 percent for the 1,500-TPD units) is attributable to ground-water monitoring including capital costs for wells, a hydrogeologic study to characterize ground-water flow and to determine appropriate placement for wells, and the annual, phase one monitoring cost.

As mentioned in Chapter IV, the Cost Model does not include high enough costs for the first phase of ground-water monitoring. The size and design combination that is most sensitive to this error is the 10-TPD unit with no liner and a vegetative cover. For this model landfill, the actual monitoring costs required by the Proposal would add 150 percent to the incremental cost per ton. For every other size and design, the effect would be less, ranging down to 7 percent for the largest unit with a synthetic/synthetic design.

The incremental costs for the other two modeled designs are influenced substantially by the cover and containment system costs. The synthetic cover system adds 42 percent to the incremental costs for the 10-TPD unit and nearly 150 percent to the incremental costs for the 1,500-TPD landfills. As discussed above, the cover costs do not exhibit large returns to scale because of the depth limitation imposed on units in the analysis. Overall, the 10-TPD incremental cost is 29 percent cover cost, 45 percent ground-water monitoring cost, and 26 percent general facility standards. Given the weaker returns to scale for cover costs, they dominate the incremental costs for the 1,500-TPD MSWLFs, accounting for 60 percent of the incremental cost. Ground-water monitoring contributes only 16 percent to the incremental costs.

The containment system, where required, is the largest component of the costs for units of all sizes. The liner, LCS, and cost of leachate treatment account for 70 percent of the incremental costs for the 1,500-TPD landfills and 54 percent of the costs for the 10-TPD landfills. At the largest units, the cover accounts for 18 percent and monitoring adds another 5 percent. For 10-TPD units, the corresponding components add 13 and 21 percent, respectively.

Later in this chapter we will use these unit costs to estimate national costs for the Proposal. First, however, we present incremental costs for existing MSWLFs and the combined cost estimates for both existing landfills and their replacement facilities.

Existing Units

The costs for existing units are very sensitive to the remaining life. In Figure V-2 we show the effect of varying the remaining life given a \$1 million expenditure at a 10-TPD landfill. The costs range from a high of \$385 per ton with one year remaining to a theoretical minimum of \$11.54. In the combined cost estimates presented later, we spread the costs for existing units over the actual remaining life of the MSWLFs. As an exercise to allow us to analyze the unit costs across the different design categories for existing landfills, however, we chose to fix the remaining life at 10 years. Therefore, we can describe the incremental costs of the regulatory requirements without also showing the effect of varying remaining life. The impact analysis, however, will account for actual remaining life as reported in the survey.

The requirements for existing units that meet the performance standard are the same as for new units that meet the design goal: the incremental costs reflect ground-water monitoring and general facility standards. As with new units, the monitoring well costs are only applied in states without equivalent monitoring programs, but this adjustment is not reflected in the unit costs presented here. Table V-2 lists the incremental cost for these unlined/vegetative designs. The \$17.58 per ton for the 10-TPD units is primarily from ground-water monitoring costs (51 percent) with the balance due to general facility standards for gas monitoring, run-on and run-off controls, and higher fees. Ground-water monitoring accounts for 31 percent of the incremental cost for the 1,500-TPD units.

Figure V-2
Effect of Varying Remaining Life
\$1 Million Cost at a 10-TPD Landfill

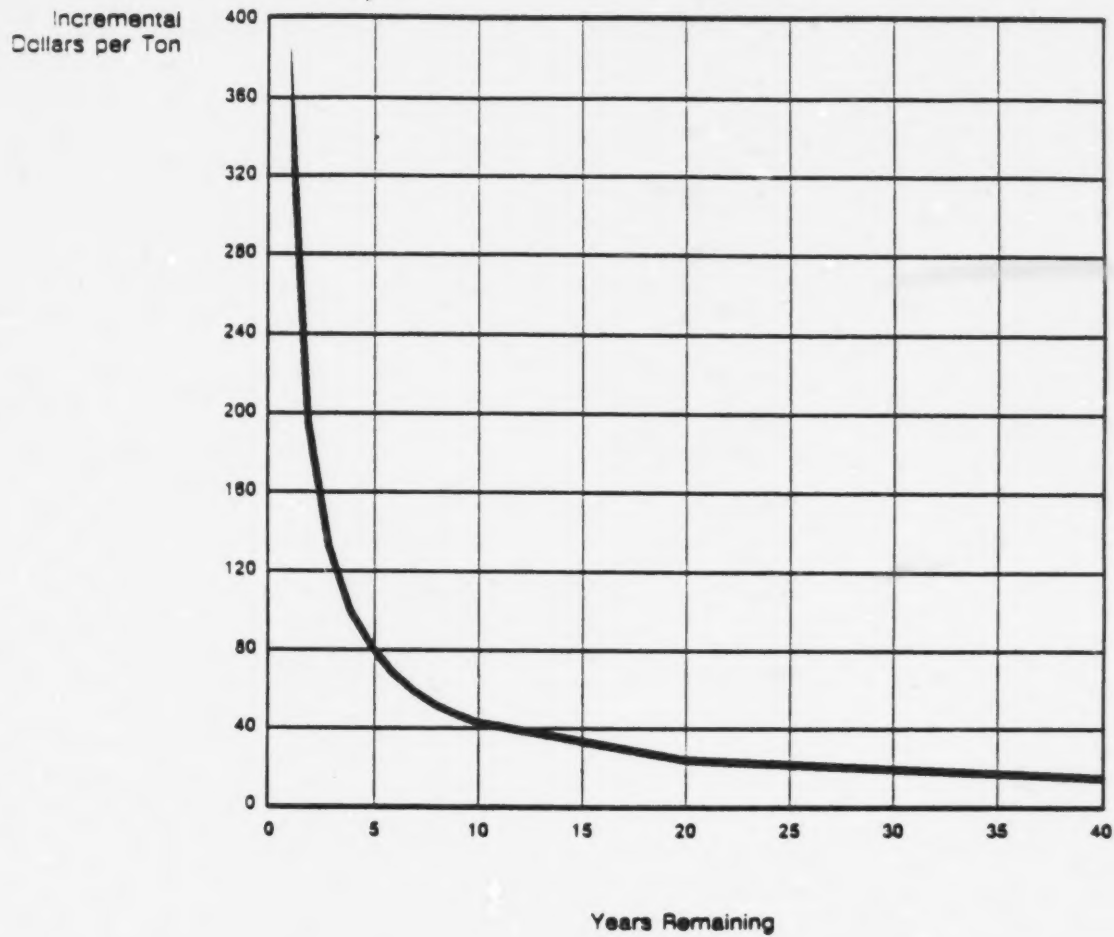


Table V-2		
INCREMENTAL COSTS FOR EXISTING LANDFILLS ¹		
Proposed Rule		
Cost per Ton		
Size (TPD)	Unlined/ Vegetative Cover	Unlined/ Synthetic Cover
10	\$17.58	\$27.37
25	10.76	18.78
75	6.10	11.55
175	4.40	8.73
375	2.95	6.28
750	1.78	4.14
1,500	1.40	4.01

¹Assuming 10 years of remaining life.

Those units that will not meet the "prevent infiltration" performance standard with a vegetative cover must install a synthetic cover at closure and will incur additional costs. These incremental costs are also presented in Table V-2. Compared to units with the unlined/vegetative design, these landfills incur costs between 56 percent and 186 percent higher. All the increase is due to the cost of the cover system. For the smallest units, the cover costs contribute 36 percent to incremental costs and monitoring adds 32 percent. At the 1,500-TPD MSWLFs, cover costs account for 65 percent of the costs with ground-water monitoring the next most expensive component at 11 percent.

Combined Costs and National
Cost Estimate: 10-Meter POC

In Chapter IV we described the combined cost measure which adds the costs for existing landfills and for replacement landfills into one present value spanning the existing landfill's remaining life plus the life of the new landfill that replaces it. The resulting annualized present value provides us with a

single (levelized) cost for each landfill. These combined costs can be thought of as a weighted average of new and existing landfill costs. With a short remaining life, for example, existing costs will have a larger influence on combined costs than will new costs. Because the combined cost measure is sensitive to both new and existing costs and is simple to use, we will rely heavily on this measure of incremental costs.

With the POC set at the unit boundary (the 10-meter POC), more of the landfills are assigned to the more stringent designs than when the 150-meter POC is used. The annualized combined cost for all landfills is \$782 million, excluding costs for corrective action and phase two monitoring which we estimate from Risk Model results. Table V-3 shows the annualized combined cost by designs. Though they account for only 28 percent of the units, the units with synthetic liners and covers incur 70 percent of total compliance costs (using the 10-meter POC).

Table V-3			
PROPOSED RULE: 10-METER POC			
Annualized Combined Cost by Design No Corrective Action			
(dollars in millions)			
<u>Design</u>	<u>Percentage of Landfills</u>	<u>Annualized Cost</u>	<u>Percentage of Total Costs</u>
Unlined/Vegetative Cover	61.3%	\$154.6	19.8%
Unlined/Synthetic Cover	10.9	78.3	10.0
Synthetic Liner/ Synthetic Cover	27.8	549.3	70.2
Total	100.0%	\$782.2	100.0%

Combined Costs and National
Cost Estimate: 150-Meter POC

The total annualized compliance cost at the 150-meter POC is \$562 million which is 28 percent lower than the cost for the 10-meter POC. Table V-4 shows that although they account for less than one-eighth of the MSWLFs, the units with synthetic covers, liners, and leachate collection systems incur nearly half of the total compliance costs.

Table V-4			
PROPOSED RULE: 150-METER POC			
Annualized Combined Cost by Design No Corrective Action			
(dollars in millions)			
<u>Design</u>	<u>Percentage of Landfills</u>	<u>Annualized Cost</u>	<u>Percentage of Total Costs</u>
Unlined/Vegetative Cover	79.1%	\$249.5	44.4%
Unlined/Synthetic Cover	8.5	45.3	8.1
Synthetic Liner/ Synthetic Cover	12.4	267.2	47.5
Total	100.0%	\$562.0	100.0%

Costs Dependent
on the Risk Model

As described in Chapter IV, corrective action and phase two monitoring both impose incremental costs on landfills under the Proposal, and for modeling purposes we base their incidence on results from the Risk Model. Corrective action is only triggered in some environmental settings and for those MSWLFs that, despite their synthetic liner and cover, will not meet the design goal at the relevant POC. These costs are added for both new and existing units. Phase two monitoring costs are added for new units only.

Corrective action incidence is determined by MSWLFs' ability to meet the design goal given their modeled designs. In Chapter IV we described how landfills were assigned to designs: corrective action is required for approximately 11 percent of new landfills given the 10-meter POC and 5 percent given the alternative POC. Costs were provided from the Subtitle D Risk Model results. The cost estimates are linked to unit size, net precipitation, and groundwater flow field. We were able to relate the cost results to surveyed landfills for size and net precipitation only, since the surveyed landfills did not report detailed characteristics of the underlying aquifer.

Corrective Action Costs: New Units and 10-Meter POC.
Table V-5 summarizes the incidence and cost of corrective action for the 10-meter POC within size/net precipitation categories used in the Risk Model. Both estimates were aggregated and weighted across the ground-water flow fields described in Chapter IV.

Table V-5			
INCIDENCE OF CORRECTIVE ACTION COSTS			
Proposed Rule: New Units and 10-Meter POC			
Size (TPD)	Net Precipitation (inches per year)	Percentage of Landfills in Settings that Incur Corrective Action Costs	Weighted Annualized Costs per Ton
1-30	<0	0%	-
	0-5	0	-
	5-15	4.3	\$7.78
	>15	2.3	7.90
30-500	<0	0%	-
	0-5	0	-
	5-15	56.3	\$0.42
	>15	42.8	0.49
500+	<0	0%	-
	0-5	0	-
	5-15	56.3	\$0.11
	>15	73.9	0.21

The costs were annualized over an infinite time period, divided by the tons of waste received, and added to the new unit costs for the design and operating standards. Annualized costs per ton range from \$0.11 to \$7.90. As present values, the costs of these corrective actions are between \$636,000 and \$1,355,000 with a median PV of \$698,000. These are weighted average costs to clean up plumes at units with synthetic covers and synthetic containment systems that still have releases that exceed the performance standard. Corrective actions costs were assigned to 11 percent of all MSWLFs under this scenario.

Corrective Action Costs: New Units and 150-Meter POC. With the POC set at 150 meters from the unit, the fraction of MSWLFs that are assigned corrective action costs is much lower than when the POC was at 10 meters. Only about 5 percent of the landfills trigger corrective action. Table V-6 shows the incidence by size/net precipitation scenarios as well as the annualized costs per ton that are added to design costs for new units. The costs per ton range from \$0.86 to \$58.65, and the present value of the cleanup costs ranges from \$5.1 million to \$6.1 million with a median of \$5.5 million. The costs for these cleanups is much higher than for cleanups with the POC at the unit boundary because these plumes are not cleaned up until they reach the 150-meter well. By this time, the area of the plumes is larger; at the same time, however, more dilution and attenuation of constituents occurs during the time the plume takes to reach this POC, so fewer corrective actions are necessary. The effect of the larger plume area dominates the lower incidence, so expected corrective action costs are higher.

Table V-6

INCIDENCE OF CORRECTIVE ACTION COSTS

Proposed Rule: New Units and 150-Meter POC

Size (TPD)	Net Precipitation (inches per year)	Percentage of Landfills in Settings that Incur Corrective Action Costs	Weighted Annualized Costs per Ton
1-30	<0	0%	-
	0-5	0	-
	5-15	3.8	\$58.65
	>15	2.2	58.65
30-500	<0	0%	-
	0-5	0	-
	5-15	20.1	\$3.54
	>15	20.3	4.03
500+	<0	0%	-
	0-5	0	-
	5-15	21.4	\$0.89
	>15	51.6	0.86

Corrective Action Costs: Existing Units. As we described in Chapter IV, the approach for existing units is the same for all the options since existing units are assumed to have the same baseline design. The incidence and cost estimates, therefore, are the same for existing units under all the regulatory options. Landfills that trigger some response to contamination will fall into one of two categories: those with the most extensive contamination (i.e., those with plumes that exceed a risk threshold at the 600-meter well) will clean up plumes; those with less extensive contamination that trigger resource damage will replace the ground-water supply only and no cleanup costs are included. As with resource damage estimates, the cost to replace water supplies is greater if ground-water wells already exist near the landfill. If no wells are nearby, the option value cost is used.

Table V-7 shows the fraction triggering corrective action and the cleanup cost, the fraction triggering replacement, and the relative costs of replacement depending on whether or not wells are downgradient from the unit.

Table V-7
INCIDENCE OF CORRECTIVE ACTION COSTS
Existing Units: All Options

Size (TPD)	Net Precipitation (inches per year)	Percentage of Landfills in Settings that Incur Cleanup Costs	Weighted Annualized Cost per Ton	Percentage of Landfills in Setting that Will Replace Ground- Water Supply	Weighted Annualized Cost per Ton to Replace:	
					Wells in Place	No Wells
1-30	<0	0%	-	34.6%	\$ 5.61	\$0.80
	0-5	0	-	33.9	12.53	1.04
	5-15	0	-	79.6	20.21	1.02
	>15	2.3	\$47.83	93.3	19.48	0.71
30-500	<0	0%	-	63.4%	\$ 0.76	\$0.07
	0-5	0	-	63.8	1.09	0.08
	5-15	43.3	\$ 7.60	56.7	1.72	0.08
	>15	51.3	9.06	48.7	2.13	0.08
500+	<0	0%	-	34.6%	\$ 0.20	\$0.02
	0-5	0	-	79.5	0.38	0.02
	5-15	46.7	\$ 1.97	53.3	0.53	0.02
	>15	72.8	2.37	27.2	0.63	0.02

Overall, 9 percent of the existing units trigger corrective action and are assigned costs to clean up the plumes immediately. The costs per ton for cleanup range from \$1.97 to \$47.83 and the present values of the cleanup costs range from \$4.1 million to \$15.4 million with a median present value of \$12.8 million. These are the most expensive cleanup costs estimated for this analysis because the plumes have been allowed to grow undetected from the existing units until the rule is in place and exceed trigger levels beyond 600 meters of plume length.

The remaining columns in the table describe the incidence and costs for units where releases cause resource damage; the costs are for ground-water supply replacement when either current or future wells are affected. Approximately 58 percent of the landfills will trigger resource damage and be assigned replacement costs. As with the entire sample of landfills, the majority of these (54 percent) are assigned option value costs (they will replace the ground-water supply at some point in the future) because there are no wells downgradient. The remainder will replace the ground-water supply immediately.

In several scenarios (e.g., 30 to 500 TPD and more than 15 inches of net precipitation), cleanup or replacement costs are incurred at every landfill. Overall, however, 58 percent of the MSWLFs incur some current or future replacement cost. Including

both corrective action (cleanup) and replacement, we estimated that 66 percent of the existing MSWLFs will trigger some response to releases. This estimate will remain the same for all the options analyzed below. These costs assume baseline (unlined/vegetative cover) units and therefore do not include incremental improvements in performance due to better covers if they are used.

Phase Two Ground-Water Monitoring Costs. The Risk Model was also used to generate conservative estimates of when constituents might first appear at the monitoring wells so that we could include costs for shifting from phase one to phase two monitoring at new units. Chapter IV describes the approach we took; we assume that all units will shift to phase two monitoring at some point in the future. The cost estimates are sensitive to the trigger time because of discounting. If we use the 10-meter POC, in the worst case constituents would reach the well in 15 years; at best they would reach it in 72 years. Using the 150-meter POC, the shortest period of time constituents would take is 45 years and the longest is 95 years. The longer delay is a function of the greater distance to the well. As described in Chapter IV, the modeled cost per sample for monitoring is lower than would be required under the Proposal.

Total Combined Costs: 10-Meter POC

The total combined cost estimates are derived from the combined cost estimates given above, which include general facility standards and design and operating standards for new and existing landfills, and from the costs dependent on the Risk Model: corrective action for new and existing units and phase two monitoring for new units. The total annualized combined cost at the 10-meter POC for the Proposal is \$880.0 million. The Risk-Model-based costs added 13 percent to the combined cost reported for the design standards. Table V-8 presents the costs by design type specified earlier. All the corrective action costs for new units are added to the synthetic/synthetic designs, but the costs for phase two monitoring and existing corrective action affect all the design types. The allocation of costs by design is only slightly different than in Table V-3. Corrective action costs for new units added approximately 13 percent to the total synthetic/synthetic design cost estimate.

Table V-8

ANNUALIZED COMBINED COST BY DESIGN

Proposal Plus Corrective Action Cost
for Existing Plus New MSWLFs:
10-Meter POC

(dollars in millions)

<u>Design</u>	<u>Percentage of Units</u>	<u>Annualized Cost</u>	<u>Percentage of Total Cost</u>
Unlined/Vegetative Cover	61.3%	\$ 173.3	19.7%
Unlined/Synthetic Cover	10.9	86.0	9.8
Synthetic Liner/ Synthetic Cover	27.8	620.7	70.5
	100.0%	\$ 880.0	100.0%

Table V-9 disaggregates the total cost of the Proposal by size categories of landfills. This demonstrates the dominance of the largest units in the total cost estimates, despite the higher unit costs for small landfills. The smallest landfills, less than 50 TPD, contribute only 16 percent of the total cost although they account for 68 percent of the MSWLFs. The largest units, representing 6 percent of all MSWLFs, account for 38 percent of the total costs.

Table V-9

ANNUALIZED COMBINED COST BY SIZE

Proposal Plus Corrective Action Cost for
Existing Plus New MSWLFs: 10-Meter POC

(dollars in millions)

<u>Size (TPD)</u>	<u>Percentage of MSWLFs</u>	<u>Annualized Cost</u>	<u>Percentage of Total Cost</u>
10	51.3%	\$ 52.3	5.9%
25	17.0	85.8	9.8
75	13.1	134.0	15.2
175	7.3	128.5	14.6
375	5.5	148.7	16.9
750	3.1	137.3	15.6
1,500	2.6	193.4	22.0
	100.0% ^a	\$ 880.0	100.0%

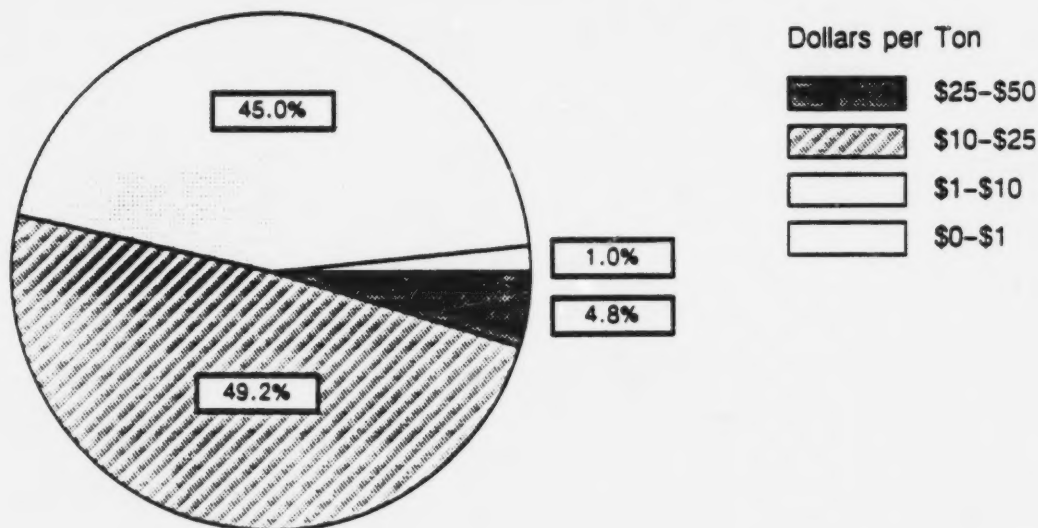
^aDoes not add because of rounding.

Figure V-3 summarizes the distribution of MSWLFs across different categories of incremental cost per ton. At the high end of the range, 4.8 percent (288) of all landfills have incremental combined costs of more than \$25 per ton. The maximum incremental cost per ton is \$40.61.

Another approach for analyzing combined costs is to estimate the percentage increase of these costs compared with the current annual operating costs for landfills as reported in the survey. Because these reported costs are much lower than the analytical baseline costs, the percentage increases are much greater. The comparison shows that 4 percent of the landfills that reported current operating costs will incur incremental cost increases of more than 500 percent. The Proposal will at least double the annual operating expenses at 46 percent of the landfills. Although it is counter to our expectations, many large percentage increases occur at large landfills as well as at small ones. We attribute this to inconsistencies in the reporting of operating costs in the survey. While we are adding O&M costs and amortized capital costs, the survey responses may only include O&M costs; therefore the cost increases above reported costs may be less than indicated by this measure.

Figure V-3

Incremental Costs to MSWLFs
Proposed Rule (10-Meter POC): Corrective Action Included



Total Combined Costs: 150-Meter POC

The total annualized combined cost for the Proposal, assuming the 150-meter compliance point, is \$691.4 million and includes all the corrective action costs. Corrective action and phase two monitoring added \$129 million or 23 percent to the combined cost estimate for the design and operating standards. Corrective action costs are more significant given the 150-meter POC because plume cleanups are much more expensive at new units. With the POC 150 meters from the unit, plumes are quite large when they are addressed. Table V-10 shows how the costs are distributed across the design types. The costs are more concentrated within the synthetic/synthetic design category than they were before corrective action. The high cleanup costs at these units increased their share of total costs to 53 percent, even though they represent only 12 percent of all MSWLFs.

Table V-10

ANNUALIZED COMBINED COST BY DESIGN

Proposal Plus Corrective Action Cost
For Existing Plus New MSWLFs:
150-Meter POC

(dollars in millions)

<u>Design</u>	<u>Percentage of Units</u>	<u>Annualized Cost</u>	<u>Percentage of Total Cost</u>
Unlined/Vegetative Cover	79.1%	\$ 271.3	39.2%
Unlined/Synthetic Cover	8.5	53.8	7.8
Synthetic Liner/ Synthetic Cover	12.4	366.3	53.0
	100.0%	\$ 691.4	100.0%

Table V-11 breaks the costs down by size category and, like the results for the 10-meter POC, shows that although these costs are lower, the bulk of the total cost comes from the largest units. The largest landfills, representing 6 percent of all MSWLFs, contribute 35 percent of the total cost.

Table V-11			
ANNUALIZED COMBINED COST BY SIZE			
Proposal Plus Corrective Action Cost for Existing Plus New MSWLFs: 150-Meter POC			
(dollars in millions)			
Size (TPD)	Percentage of MSWLFs	Annualized Cost	Percentage of Total Cost
10	51.3%	\$ 47.3	6.8%
25	17.0	72.2	10.4
75	13.1	107.6	15.6
175	7.3	95.6	13.8
375	5.5	130.3	18.9
750	3.1	93.4	13.5
1,500	2.6	145.0	21.0
	100.0% ^a	\$ 691.4	100.0%

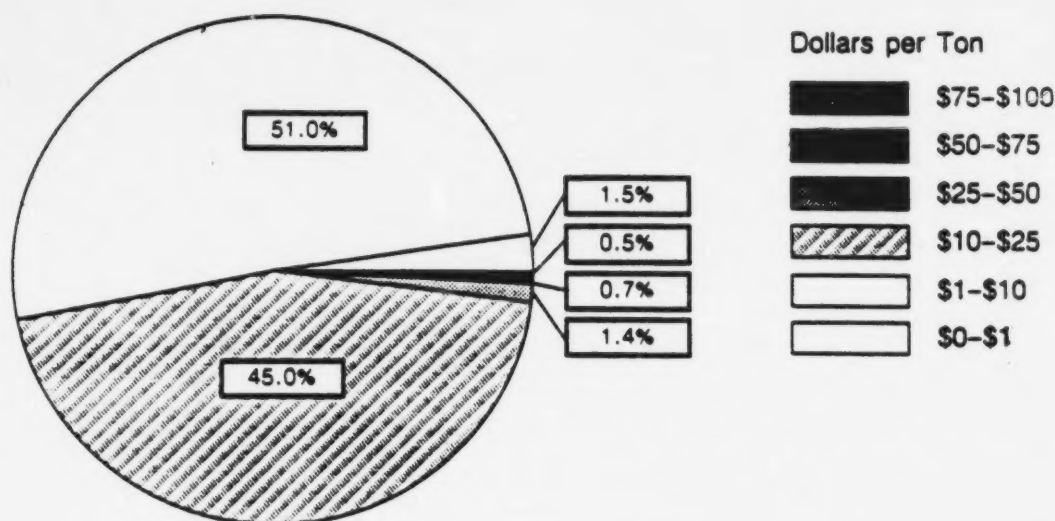
^aDoes not add because of rounding.

In order to compare the effects of the alternative compliance point, we also categorized the incremental costs in terms of dollars per ton (Figure V-4) and the percentage increase above the survey-reported annual operating costs. The average costs are lower for the 150-meter POC, but there are higher costs at some landfills because of corrective action costs. The bulk of the landfills have costs below \$25 per ton (97.5 percent), but because of corrective action, a few landfills have combined costs per ton of over \$75; the maximum cost per ton is \$81.39. This infrequent, high cost results from expensive corrective actions that are triggered at the 150-meter POC.

The percentage increases above annual operating costs (reported in the MSWLF survey) are slightly less than those under the 10-meter POC. About 38 percent of the landfills would have at least 100 percent increases in their reported annual cost. Again, these percentage increases may be overstated to the extent that the survey responses do not include amortization of capital costs.

Figure V-4

Incremental Costs to MSWLFs
Proposed Rule (150-Meter POC): Corrective Action Included



Note: Percentages do not add because of rounding.

Alternative 1: Subtitle C Cover and Containment Systems

This Alternative imposes uniform requirements on all landfills, regardless of their location. The requirements are more stringent than those modeled for the Proposal: the ground-water monitoring parameters modeled are more extensive (although still less than those required by the Proposal) and the cover and containment system designs comply with those required at Subtitle C landfills. Ground-water monitoring is not phased in under this option, though it is for each of the others. We did exclude capital costs for wells from the incremental cost if EPA identified the state as currently requiring monitoring. Finally, the post-closure care period is extended as it is under the other options.

New Units

The incremental costs per ton for new units under Alternative 1 are presented in Table V-12. In order to assign the correct costs, we used MSWLF survey results to determine whether the clay needed for the landfill cover and liner was available at the site: the 76.7 percent of units reporting clay or sandy clay as the primary or secondary soil type are assumed to have adequate clay on site. The first costs we will review are for these MSWLFs with on-site clay.

Table V-12		
INCREMENTAL COSTS FOR NEW LANDFILLS		
Alternative 1		
Size (TPD)	Cost per Ton	
	On-site Clay	Off-site Clay
10	\$68.83	\$83.62
25	49.38	61.40
75	29.77	37.82
175	22.51	28.88
375	16.21	21.00
750	11.28	14.71
1,500	11.97	15.78

The incremental cost per ton is \$68.83 for the 10-TPD units, declining to \$11.28 for 750-TPD landfills. The majority of the cost is attributable to the cover and containment system requirements. The liner and cover costs account for an even greater percentage of the costs than they did in the most stringent design under the Proposal. In fact, the LCS, containment, and cover costs account for between 86 and 95 percent of the incremental costs.

The dominant component of the \$68.83 for 10-TPD units is the containment system and the accompanying leachate collection and treatment, which account for about 54 percent of the incremental cost. The cover system accounts for about 32 percent of the increment while the additional ground-water monitoring parameters add less than 8 percent. The balance includes the costs of the other requirements, such as run-on and run-off controls, gas monitoring, ground-water monitoring, and higher fees and QA.

For the 1,500-TPD facilities, the incremental cost is \$11.97, of which three-quarters is for the containment system and leachate collection and treatment. Eighteen percent is for the

cover system and the balance is made up of all other requirements. The higher ground-water monitoring costs comprise less than 1 percent of the incremental cost per ton for the large units.

The unit cost for clay from off site is over twice the cost for on-site clay. The new unit costs per ton for Alternative 1 are, accordingly, between 21 and 32 percent higher if off-site clay is used.

Existing Units

As with the Proposal, we fixed the remaining life at 10 years to illustrate the magnitude of existing costs across size categories. The incremental costs per ton are lower for existing units (assuming 10 years of remaining life) than for new, even though the shorter amortization period might suggest that the costs would be higher. They are lower because containment and leachate management systems costs are not included for existing units.

Table V-13 presents the incremental costs per ton. For units with on-site clay, the incremental costs per ton range from \$59.49 for 10-TPD units to \$6.12 for 1,500-TPD units. At small MSWLFs, 43 percent of the incremental costs is due to ground-water monitoring, which includes not only the wells but also the expanded set of monitoring parameters. The cover system accounts for another 29 percent of the cost. The balance consists of post-closure costs, higher fees for construction, surface-water controls, and gas monitoring.

Table V-13		
INCREMENTAL COSTS FOR EXISTING LANDFILLS		
Alternative 1		
Size (TPD)	Cost per Ton	
	On-site Clay	Off-site Clay
10	\$59.49	\$68.02
25	37.73	44.83
75	20.13	24.99
175	14.32	18.21
375	9.61	12.55
750	6.41	8.54
1,500	6.12	8.48

For 1,500-TPD landfills, the cover costs dominate all others, accounting for 74 percent of the incremental costs. Another 17 percent is from ground-water monitoring.

Units that must obtain clay from off site have incremental costs between 14 and 39 percent higher than those using on-site clay. As expected, the increases are larger for large units where cover costs dominate the incremental cost estimates. The incremental costs for 10-TPD units are dominated by ground-water monitoring and the cover system, each accounting for 38 percent. At 1,500-TPD MSWLFs, 83 percent of the incremental cost is attributable to the cover system and 13 percent to monitoring.

Combined Costs: National Cost Estimates

Given the relatively high cost of the cover and containment systems and the fact that all the units are required to install these more elaborate systems, we expect the costs to exceed those for the Proposal. The annualized combined costs (without corrective action) for the 6,034 landfills is \$3,269 million, more than four times the cost of the Proposal. Table V-14 displays the annualized combined costs by clay availability.

Table V-14			
ANNUALIZED COMBINED COST			
Alternative 1: Cost by Clay Availability			
(dollars in millions)			
<u>Clay</u>	<u>Percentage of Landfills</u>	<u>Cost</u>	<u>Percentage of Total Costs</u>
On-site	76.7%	\$2,665	81.5%
Off-site	23.3	604	18.5
Total	100.0%	\$3,269	100.0%

Clay is available on-site at 76.7 percent of the landfills. The survey data also show that the typical size of units with clay on-site is slightly larger than those without clay. As a result of the relationship between size and clay availability, the mean cost per unit with on-site clay is higher than the mean without clay, even though off-site clay is much more expensive. Overall, units with on-site clay account for 81.5 percent of the cost.

Costs Dependent on Risk Model Results

As with the Proposal, we used the Risk Model to estimate the fraction of landfills that would trigger corrective action at new and existing units. The incidence and unit costs for corrective action at new units is shown in Table V-15. MSWLFs in many of the environmental settings will never trigger cleanup because constituents will never exceed the thresholds. For the larger units, especially in wetter climates, a majority of the units will trigger corrective action. The present values of the cleanup costs range from \$674,000 to \$1,355,000 with a median of \$709,000.

The corrective action cost and incidence for existing units is the same as estimated for the Proposal. Table V-7 includes all the details on the modeling results. Finally, unlike the Proposal and Alternative 2, Alternative 1 imposes no incremental costs for phase two monitoring since these units are already testing for an expanded set of parameters.

Table V-15

INCIDENCE OF CORRECTIVE ACTION COSTS ALTERNATIVE 1: NEW UNITS

Size (TPD)	Net Precipitation (inches per year)	Percentage of Landfills in Settings that Incur Corrective Action Costs	Weighted Annualized Costs per Ton
1-30	<0	0%	-
	0-5	0	-
	5-15	4.3	\$7.78
	>15	2.3	7.90
30-500	<0	0%	-
	0-5	0	-
	5-15	40.2	\$0.47
	>15	42.8	0.49
500+	<0	0%	-
	0-5	0	-
	5-15	56.3	\$0.11
	>15	73.9	0.21

Total Combined Costs: Alternative 1

Table V-16 presents the annualized combined cost including corrective action for new and existing units. The remedial measures add 2 percent to the total of the design and operating costs, a small percentage increase because of the magnitude of the design costs already included. Rather than presenting costs by clay availability, which does not affect corrective action costs, we present costs by size. The total combined cost of \$3,341 million is the highest of any option analyzed and is dominated by very high costs for design standards at the largest units: over one-fourth of the cost is borne by 2.6 percent of the units.

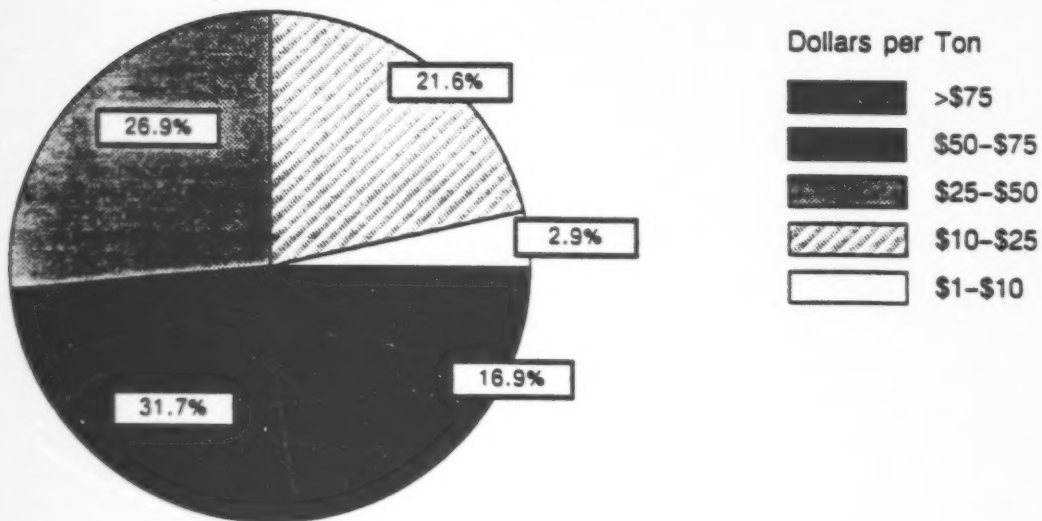
Table V-16			
ANNUALIZED COMBINED COST BY SIZE			
Alternative 1 Including Corrective Action Cost for New Plus Existing MSWLFs			
(dollars in millions)			
Size (TPD)	Percentage of MSWLFs	Annualized Cost	Percentage of Total Cost
10	51.3%	\$ 220.1	6.6%
25	17.0	327.3	9.8
75	13.1	481.4	14.4
175	7.3	424.5	12.7
375	5.5	527.6	15.8
750	3.1	445.1	13.3
1,500	2.6	914.9	27.4
	100.0% ^a	\$3,341.0 ^a	100.0%

^aDoes not add because of rounding.

The incremental costs per ton under this Alternative are much larger than under the Proposal. Figure V-5 shows that nearly 49 percent will incur incremental costs greater than \$50 per ton. The maximum cost per ton is \$108.

Figure V-5

Incremental Costs to MSWLFs
Alternative 1: Corrective Action Included



Alternative 2

Alternative 2 imposes different costs on MSWLFs depending on their location and requires the use of engineered controls to meet performance standards for infiltration and leachate release. We will present unit costs for new and existing landfills and aggregate them to produce national combined cost estimates for the Alternative.

New Units

The costs for new units assume that construction begins immediately and that the units will operate for 20 years. In the economic analysis and for the combined costs, the starting date is delayed until the expected life of the existing unit is reached. Table V-17 summarizes the annualized incremental costs per ton for each design category, described in Chapter IV. The costs for a synthetic/synthetic design with LCS are the highest, between 3 and 8 times higher than the incremental costs for the least expensive design, depending on size.

Table V-17

INCREMENTAL COSTS FOR NEW LANDFILLS

Alternative 2

Size (TPD)	Cost per Ton							
	Unlined/ Vegetative Cover	Unlined/ Synthetic Cover	Clay (on-site) Vegetative Cover	Clay (off-site) Vegetative Cover	Synthetic Liner/ Vegetative Cover & LCS	Synthetic Liner/ Synthetic Cover & LCS	Unlined/ Vegetative Cover & LCS	Unlined/ Synthetic Cover & LCS
10	\$9.70	\$13.88	\$17.33	\$23.87	\$26.83	\$30.83	\$22.60	\$26.59
25	5.93	9.36	12.18	17.55	19.79	23.07	16.34	19.61
75	3.37	5.69	7.58	11.19	12.49	14.71	10.17	12.40
175	2.42	4.27	5.76	8.62	9.62	11.39	7.79	9.56
375	1.62	3.04	4.17	6.36	7.09	8.45	5.69	7.05
750	0.97	1.97	2.76	4.30	4.81	5.78	3.83	4.79
1,500	0.75	1.86	2.75	4.48	5.03	6.09	3.93	4.99

The costs for all designs include the same general facility standards imposed under the Proposal. The cost for assessing risk is not included, but we did include a cost for determining precipitation (\$200 for new and existing units) and travel time (\$3,000 for new units only). The incremental cost per ton for these general facility requirements ranges from \$9.70 for the smallest unit down to \$0.75 for the largest. About 66 percent of the incremental costs for the 10-TPD units arise from ground-water monitoring. The costs include capital costs for wells, the hydrogeologic study to characterize ground-water flow and determine appropriate placement for wells, and the annual monitoring cost. Remaining major costs include gas monitoring, run-on and run-off controls, and additional fees for design quality assurance (QA). Ground-water monitoring accounts for only 39 percent of the incremental cost for the largest units. The dominant remaining costs are the higher engineering fees associated with excavation and site development costs and QA fees for the design. These are the only costs for units assigned to the unlined/vegetative cover design.

The costs for the remaining designs are higher because of the various combinations of covers, liners, and leachate collection systems.

The next design shown in Table V-17 is unlined with a synthetic cover, a design that was also analyzed under the Proposal. The synthetic cover cost adds about \$4 per ton to the cost of the 10-TPD unlined/vegetative (U/V) design. The \$13.88 incremental cost for 10-TPD units is dominated by ground-water monitoring

(46 percent) and the cover (30 percent). For 1500-TPD MSWLFs, the cover dominates incremental costs, accounting for 60 percent of the cost, while ground-water monitoring adds another 16 percent.

The designs with clay liners are applicable when no LCS is required, but the owner/operator must increase the travel time. The clay liner is the most expensive component of the costs for these designs. For the smallest model size the liner accounts for 44 percent of the incremental cost if clay is available on-site, or 59 percent if clay is brought from off-site. Ground-water monitoring is the most significant other cost accounting for 37 percent of the on-site clay design cost and 27 percent of the off-site clay cost. For 1500-TPD units, the liner is even more dominant, accounting for 72 percent of the cost using on-site clay and 83 percent if off-site clay is used.

The next design, synthetic liner with LCS, is more expensive than either of the clay designs. The combined liner/LCS design adds over \$17 per ton to the cost for a 10-TPD U/V design. The containment and leachate system together account for 64 percent of the incremental design cost for 10-TPD units. For 1500-TPD units, the system accounts for 85 percent of the cost.

The most expensive design analyzed is the synthetic liner, synthetic cover, and LCS combination. This is the same design analyzed under the Proposal. As with the other designs we modeled, these location-specific requirements account for most of the incremental cost attributed to the Proposal. For the largest units, the cover, liner, and LCS comprise 88 percent of the incremental cost: among those components the LCS is the most expensive accounting for about half of the increment. At the 10-TPD size, the three requirements account for 69 percent of incremental costs.

The final two designs analyzed for new units add components of other designs to the U/V design. Each of the designs has an LCS over native soil and is only assigned if the MSWLF is located in clay. The cost per ton for the U/V design with an LCS is \$22.60 for the 10-TPD and ranges down to \$3.83 for the 750-TPD. The LCS dominates the incremental cost estimate accounting for 57 percent of the 10-TPD cost and 81 percent of the 1500-TPD cost. The final design adds a synthetic cover to the LCS over native clay. The LCS cost is still the largest component at 10-TPD landfills accounting for 49 percent, followed by ground-water monitoring (24 percent), and the cover (16 percent). At 1500-TPD units the LCS accounts for 64 percent of the incremental cost, the cover 22 percent, and ground-water monitoring only 6 percent.

Existing Units

The requirements for existing units are the same as for the new U/V design if units are in areas with zero or negative net precipitation. If net precipitation is positive, the unlined/synthetic (U/S) design is required. Again, we emphasize that these designs were chosen for modeling purposes and assumed to meet the performance standards. Table V-18 presents incremental costs per ton for each design assuming 10 years of remaining life. As with new units, the largest contributor to incremental cost for the 10-TPD units is ground-water monitoring, which accounts for 67 percent of the U/V cost and 43 percent of the U/S cost. The synthetic cover accounts for 36 percent of the U/S design. If we look at the component costs for the largest units, the single most expensive part of the U/V design is ground-water monitoring (36 percent). The U/S design is 65 percent cover cost and 13 percent ground-water monitoring. Gas monitoring, quality assurance fees, and run-on/run-off controls make up the balance.

Table V-18		
INCREMENTAL COSTS FOR EXISTING LANDFILLS		
Alternative 2		
Size (TPD)	Cost per Ton	
	<u>Vegetative Cover (U/V)</u>	<u>Synthetic Cover (U/S)</u>
10	\$17.05	\$26.83
25	10.54	18.57
75	6.03	11.46
175	4.37	8.70
375	2.94	6.26
750	1.77	4.13
1,500	1.40	4.00

We have shown for both new and existing units that ground-water monitoring dominates the cost estimates for small units with no location-related cover or liner requirements. Once the units are subject to these site-specific requirements, however, the cover or containment system cost dominates the incremental cost estimates.

Combined Costs and
National Cost Estimate

For this Alternative, the annualized combined cost for all landfills is \$1,337 million, excluding corrective action. We disaggregated the costs by designs as described in Table IV-1. The results, shown in Table V-19, indicate that the synthetic/synthetic design is assigned to the majority of MSWLFs (56.1 percent) and accounts for an even greater majority (81.1 percent) of the total cost without corrective action. No other design category contributes more than 6.7 percent to total cost without corrective action.

Table V-19			
ALTERNATIVE 2			
Annualized Combined Cost by Design Without Corrective Action			
(dollars in millions)			
<u>Design</u>	<u>Percentage of MSWLFs</u>	<u>Annualized Cost</u>	<u>Percentage of Total Cost</u>
Unlined/ Vegetative	17.6%	\$ 50.2	3.8%
Unlined/ Synthetic	2.1	28.0	2.1
Clay/ Vegetative	5.3	48.9	3.7
Synthetic/ Vegetative and LCS	7.8	28.4	2.1
Synthetic/ Synthetic and LCS	56.1	1,084.6	81.1
Unlined/ Vegetative and LCS	3.5	7.9	0.6
Unlined/ Synthetic and LCS	7.6	89.0	6.7
	100.0%	\$1,336.9 ^a	100.0% ^a
^a Does not add because of rounding.			

Costs Dependent
on the Risk Model

Corrective action costs were provided from the Risk Model results. Table V-20 shows that within each size/net precipitation category, we estimated the proportion of new units where corrective action would be triggered and an average cost. Annualized costs per ton range from \$0.11 to \$7.90. As present values, the costs range from \$636,000 to \$1,355,000 with a median cost of \$698,000. We assigned corrective action costs to 11 percent of the new units.

Table V-20			
INCIDENCE OF CORRECTIVE ACTION COSTS			
ALTERNATIVE 2			
Size (TPD)	Net Precipitation (inches per year)	Percentage of Landfills in Settings that Incur Corrective Action Costs	Weighted Annualized Costs per Ton
1-30	<0	0%	-
	0-5	0	-
	5-15	4.3	\$7.78
	>15	2.3	7.90
30-500	<0	0%	-
	0-5	0	-
	5-15	56.3	\$0.42
	>15	42.8	0.49
500+	<0	0%	-
	0-5	0	-
	5-15	56.3	\$0.11
	>15	73.9	0.21

Corrective action costs were assigned to existing units as described under the Proposal. We estimated that 66 percent of the units trigger some response to releases.

The incremental costs for phase two monitoring were imposed on new landfills taking into account environmental setting and unit design. We estimated that constituents could reach monitoring wells between 38 and 74 years after the unit begins accepting waste. The incremental costs per ton of the phase two monitoring range between \$0.03 and \$1.08.

Table V-21 shows the Alternative 2 costs including corrective action and phased ground-water monitoring. The annualized combined cost increases \$90 million or 7 percent. Costs are distributed nearly the same as in Table V-19. Corrective action does not have a large effect on total costs because much more is spent on design standards than under the Proposal.

Table V-21			
ALTERNATIVE 2			
Annualized Combined Cost by Design Including Corrective Action			
(dollars in millions)			
<u>Design</u>	<u>Percentage of MSWLFs</u>	<u>Annualized Cost</u>	<u>Percentage of Total Cost</u>
Unlined/ Vegetative	17.6%	\$ 52.1	3.7%
Unlined/ Synthetic	2.1	29.4	2.1
Clay/ Vegetative	5.3	50.2	3.5
Synthetic/ Vegetative and LCS	7.8	29.7	2.1
Synthetic/ Synthetic and LCS	56.1	1,166.6	81.8
Unlined/ Vegetative and LCS	3.5	8.1	0.6
Unlined/ Synthetic and LCS	7.6	90.7	6.4
	100.0%	\$1,426.9 ^a	100.0% ^a
^a Does not add because of rounding.			

We also disaggregated the costs by size categories to show how the smallest units, which bear the highest costs per ton, contribute a relatively small share to total costs of the Alternative. Table V-22 shows the total annualized cost for Alternative 2 by size category. At one extreme, the smallest units account for 51.3 percent of the population, but only 5.6 percent of the total cost. The total cost estimate is thus very sensitive to the costs for the largest units, with the largest units (6 percent of all MSWLFs) accounting for 42 percent of the cost.

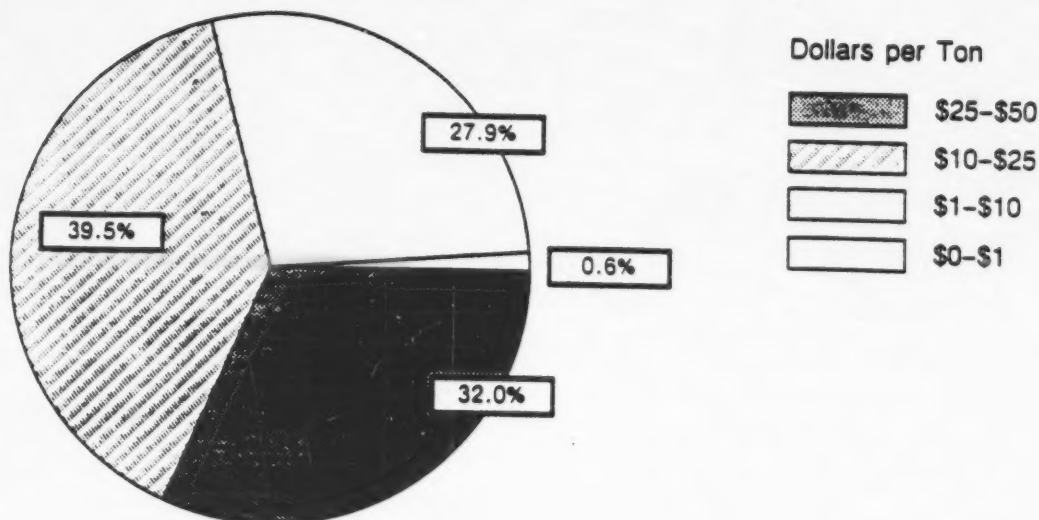
Table V-22			
ANNUALIZED COMBINED COST BY SIZE			
Alternative 2 Including Corrective Action Cost for New Plus Existing MSWLFs			
(dollars in millions)			
Size (TPD)	Percentage of MSWLFs	Annualized Cost	Percentage of Total Cost
10	51.3%	\$ 79.6	5.6%
25	17.0	128.6	9.0
75	13.1	195.1	13.7
175	7.3	191.4	13.4
375	5.5	236.4	16.6
750	3.1	204.4	14.3
1,500	2.6	391.3	27.4
	100.0% ^a	\$1,426.9 ^a	100.0%

^aDoes not add because of rounding.

Finally, we arrayed the incremental costs for the categorical Alternative by cost categories. Figure V-6 shows that combined costs per ton range from less than \$1 to nearly \$50, with most falling between \$10 and \$50. The incremental costs are generally higher than for the Proposal, but less than Alternative 1.

Figure V-6

Incremental Combined Costs to MSWLFs
Alternative 2: Corrective Action Included



Alternative 3: Statutory Minimum

As the name implies, this option requires similar provisions to those mandated in the 1984 Hazardous and Solid Waste Amendments. All units monitor ground water, provide extended post-closure care, and perform corrective action as required; no location standards are included. As with Alternative 1, the requirements are imposed uniformly on all landfills, regardless of their location. Since the Alternative includes no containment system or leachate collection system requirements, the requirements are the same for existing units and new units. As in the other options, capital costs for ground-water monitoring wells are not included for landfills in states with equivalent programs as determined by EPA.

New Units

As in the other options, new landfills are assumed to begin operation immediately and receive waste for 20 years. Given these assumptions, the incremental costs per ton are summarized

in Table V-23. Among new units, the costs range from \$6.65 for the 10-TPD landfills to \$0.29 for the 1,500-TPD units. The costs are dominated by ground-water monitoring costs, which account for 98 percent of the costs at 10-TPD units and 86 percent at the 1,500-TPD units. Costs for post-closure care maintenance make up the rest of the incremental costs.

Table V-23		
INCREMENTAL COSTS FOR NEW AND EXISTING LANDFILLS		
Alternative J		
Size (TPD)	Cost per Ton	
	New Units	Existing Units ¹
10	\$ 6.65	\$11.64
25	4.07	7.11
75	2.14	3.74
175	1.54	2.69
375	1.00	1.75
750	0.52	0.91
1,500	0.29	0.51

¹ Assumes 10 years of remaining life.

Existing Units

With the remaining life set at 10 years, the incremental costs for existing units are higher than for new units. They range from \$11.64 per ton to \$0.51 per ton and are also listed in Table V-23. The same requirements are imposed on both new and existing units, but the existing MSWLFs have only half the remaining life over which to amortize capital costs. Monitoring accounts for 98 percent of these costs for both 10-TPD and 1,500-TPD landfills.

Combined Costs and National Cost Estimates

The combined annualized cost for monitoring and post-closure care is \$117 million. These costs do not include corrective action costs, which are presented later. These costs assume sampling costs that are much lower than those described in the proposed rule. Monitoring for an expanded list of parameters

would increase these costs. We also excluded costs for ground-water monitoring wells at landfills in states with existing monitoring requirements. The range of incremental costs is much smaller than it is for other options: none of the landfills incur combined incremental costs above \$10 per ton.

Corrective Action Costs

The corrective action costs added \$302 million to the combined annualized cost of the Alternative, a nearly four-fold increase. Table V-24 summarizes the total incremental cost of this Alternative including corrective action. The costs are the least skewed toward large units of any we estimated, but the largest 6 percent still incur 23 percent of the cost. Corrective action costs dominate the estimates and are triggered at units of all sizes.

Table V-24			
ANNUALIZED COMBINED COST BY SIZE			
Alternative 3 Including Corrective Action Cost for New Plus Existing MSWLFs			
(dollars in millions)			
Size (TPD)	Percentage of MSWLFs	Annualized Cost	Percentage of Total Cost
10	51.3%	\$ 60.3	14.4%
25	17.0	68.2	16.3
75	13.1	56.4	13.4
175	7.3	69.1	16.5
375	5.5	67.6	16.1
750	3.1	42.7	10.2
1,500	2.6	55.1	13.1
	100.0% ^a	\$419.4	100.0%

^aDoes not add because of rounding.

For this Alternative, the model estimated that 39 percent of new MSWLFs would trigger corrective action. The incidence of corrective action costs varied depending on the size of the unit and the environmental setting. In specific settings, however, the probability could be much higher or lower. Table V-25

summarizes the incidence of corrective action costs on landfills. The table also shows the weighted, annualized cost per ton for corrective action in each setting. The annualized costs per ton range from \$45 for the small units down to \$0.36 for large units. The present value of the clean-up costs for new MSWLFs ranges from \$1.8 million to \$9.9 million with a median of \$3.9 million. These cleanup costs for new units are high compared with those in the other Alternatives because no preventive design features are included for these units.

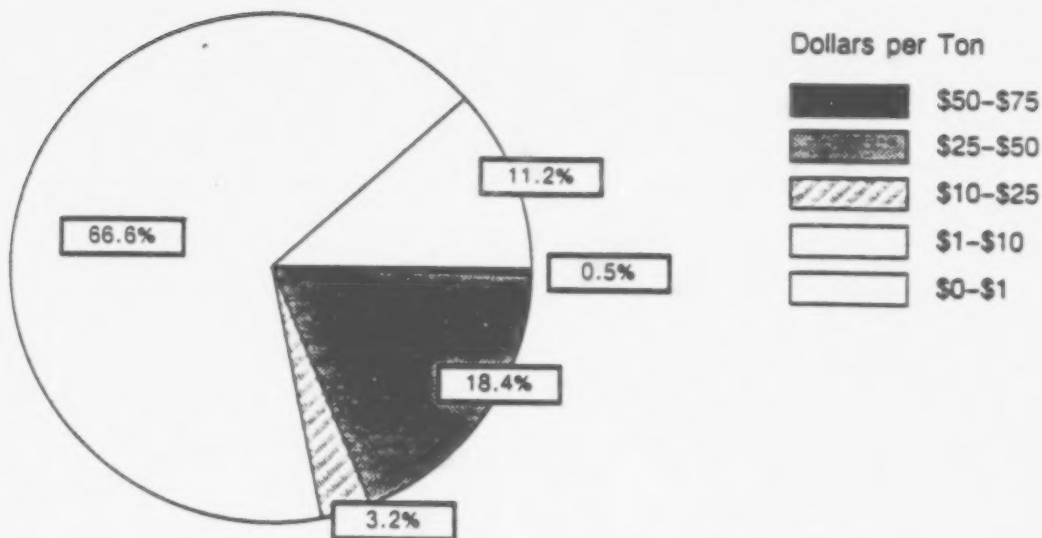
Table V-25			
INCIDENCE OF CORRECTIVE ACTION COSTS			
ALTERNATIVE 3: NEW UNITS			
Size (TPD)	Net Precipitation (inches per year)	Percentage of Landfills in Settings that Incur Corrective Action Costs	Weighted Annualized Costs per Ton
1-30	<0	0%	-
	0-5	0	-
	5-15	73.0	\$35.40
	>15	73.9	45.03
30-500	<0	0%	-
	5-15	32.3	\$ 1.19
	>15	77.6	2.82
		95.6	4.85
500+	<0	0%	-
	0-5	34.3	\$ 0.36
	5-15	83.0	0.86
	>15	100.0	1.52

Figure V-7 shows how landfills are distributed across various categories of incremental cost per ton. With corrective action, the maximum cost is \$54.45 per ton. The majority of costs are between \$1 and \$10 per ton.

Corrective action adds about 260 percent to the combined annualized costs for Alternative 3, while it added between 13 and 23 percent to the costs for the Proposal. Since there are no containment or leachate collection systems in Alternative 3, more releases occur and, therefore, much higher corrective action costs are incurred.

Figure V-7

Incremental Combined Costs to MSWLFs
Alternative 3: Corrective Action Included



Note: Percentages do not add because of rounding.

Cost Summary

The combined annualized costs for the four options range from \$419 million for Alternative 3 up to \$3,341 million for Alternative 1. The Proposal falls near the lower end of this range, given either POC. The costs with and without corrective action are summarized in Table V-26. The relative costs across options are affected by the stringency of the requirements only, since the size distribution across units and the range of remaining lives are constant across options. Corrective action is triggered under all options and is included for existing units, assuming a mix of ground-water cleanup and water-supply replacement. The Proposal (10-meter POC) costs are higher but less influenced by corrective action than the Proposal costs with a 150-meter POC in force. When corrective action costs are included, the 150-meter POC loses some of its cost advantage. Both, however, are less expensive (by about half) than the categorical Alternative.

Table V-26

COMBINED ANNUALIZED COSTS: NATIONAL ESTIMATES

(dollars in millions)

Option	No Corrective Action	Including Corrective Action	Percentage of Total Cost Contributed by Corrective Action
Proposal: 10-meter POC	\$782.2	\$ 880.0	11.1%
Proposal: 150-meter POC	562.0	691.4	18.7
Alternative 1	3,268.6	3,341.0	2.2
Alternative 2	1,336.9	1,426.9	6.3
Alternative 3	117.1	419.4	72.1

Costs per Landfill

We also disaggregated costs into annualized combined costs per landfill to compare the statistics across options. Table V-27 presents the median, maximum, and minimum costs per unit. The Subtitle C Alternative has the highest incremental median cost (\$211,000 per year), by a factor of 3.3 over the next highest, the categorical Alternative. The other options follow in the same order as the total costs for the maximum and minimum as well.

Table V-27

COMBINED ANNUALIZED COSTS: COSTS PER LANDFILL, INCLUDING CORRECTIVE ACTION

(thousands of dollars)

Statistics	Option				
	Proposal (10-meter POC)	Proposal (150-meter POC)	Alternative 1	Alternative 2	Alternative 3
Median	\$ 44	\$ 39	\$ 211	\$ 64	\$ 20
Maximum	5,555	3,106	18,007	7,036	1,049
Minimum	2	1	7	1	0.3

Range of Costs per Ton

In the previous results sections we reported the distribution of MSWLFs across categories of incremental cost per ton. Table V-28 summarizes these assignments across all the options and shows not only the range of incremental costs, but how tightly clustered landfills are across the cost categories. The Proposal has the most tightly clustered costs, with at least 96 percent of the costs falling between \$1 and \$25 per ton using either POC. Alternative 1 spans the broadest range, with costs as low as \$4 and as high as \$108. Alternative 1 is also the only option with a significant fraction of incremental costs above \$50 per ton (49 percent).

Table V-28					
COMBINED INCREMENTAL COSTS PER TON BY OPTION					
(corrective action included)					
Percentage of MSWLFs in Range					
Cost Range (cost per ton)	Proposal (10-meter POC)	Proposal (150-meter POC)	Alternative 1	Alternative 2	Alternative 3
>\$100	0%	0%	1%	0%	0%
\$75-\$100	0	1	16	0	0
\$50-\$75	0	1	32	0	1
\$25-\$50	5	1	27	32	18
\$10-\$25	49	45	21	39	3
\$1-\$10	45	51	3	28	67
\$0-\$1	1	1	0	1	11

The Proposal (10-meter POC) imposes maximum costs per ton of \$40.61 (Table V-29), but costs are less than \$25 per ton at 95 percent of the landfills. The median cost per ton is \$11.01. The 150-meter POC would impose slightly lower median costs, but the maximum is much higher, ranging up to \$81.39 because of corrective action.

Table V-29					
COMBINED INCREMENTAL COSTS PER TON BY OPTION					
(corrective action included)					
	Proposal (10-meter POC)	Proposal (150-meter POC)	Alternative 1	Alternative 2	Alternative 3
Median	\$11.01	\$ 9.54	\$ 47.58	\$15.62	\$ 5.17
Maximum	40.61	81.39	108.11	48.38	54.45
Minimum	0.76	0.75	4.01	0.75	0.06

Alternative 1 imposes costs across a much broader range, from a maximum incremental cost per ton of \$108.11 to a minimum of \$4.01. Compared to the Proposal, the distribution has shifted up substantially, as shown by the median, which increased about four-fold. Alternative 2 is less expensive for the typical landfill, with a median cost per ton of \$15.62, above either Proposal cost. The maximum cost is \$48.38.

Alternative 3 has the lowest median costs, \$5.17 per ton, and the largest fraction of landfills with costs below \$10 (78 percent versus only 3 percent in Alternative 1). At the same time, however, the maximum cost per ton is relatively high at \$54.45.

Conclusion

Alternatives 1 and 2 both impose total costs higher than the Proposal, although one imposes uniform requirements across all landfills and the other tailors designs to units' location. Both involve extensive design standards and are oriented toward preventing releases.

Alternative 3 has lower costs than the Proposal; the lower costs of compliance are a function of its reliance on response to releases. Only units that trigger corrective action are subject to the highest costs. Finally, the two versions of the Proposal have similar costs, but the version where a state may choose an alternative compliance point up to 150 meters from the unit boundary is less expensive. Higher corrective action costs narrow the gap, but it is still less expensive to meet the performance standard if the POC is 150 meters from the landfill.

ECONOMIC IMPACTS

Disposal of solid waste is one of many functions performed by local governments. Many municipalities own and operate their own MSWLFs, some participate in regional landfills operated by counties or nearby communities, others contract with private landfills, and some rely on other means to dispose of MSW such as participating in resource recovery facilities. All communities incur some cost for solid waste disposal regardless of whether this cost appears as a line item in a municipality's budget or as a fee or tax that its citizens pay back to the municipality, to a private hauler, or to another government.

This section focuses on the impacts to communities and households that are served by MSWLFs using the methodology

described in Chapter IV and the costs estimated in the previous section of this chapter. The section begins with a discussion of the impacts of the regulatory options, focusing first on the proposed rule and then on a comparison of the alternatives. We conclude the section with a discussion of the baseline financial capability of municipalities.

Two types of impacts are discussed: impacts on municipalities themselves and impacts on the households served by these municipalities. To measure impacts on municipalities, we compared the incremental costs of the options with each municipality's total current expenditures to calculate cost as a percentage of expenditures (CPE). We measured impacts on households by calculating incremental cost per household (CPH) and cost per household as a percentage of median household income (CPMHI). In all cases, we present the impacts of the combined costs on both new and existing landfills, including corrective action costs. Communities are classified as having severe impacts if CPE or CPMHI exceeds 1 percent or if CPH exceeds \$220. Chapter IV explains how these threshold levels were selected.

Impacts of the Proposed Rule

The discussion below summarizes the impacts of the Proposal, using both the 10-meter and 150-meter POCs, examining how the impacts on communities and households vary by design type, state, and type of landfill owner.

Economic impacts vary considerably by assigned design. The more severe impacts are found in communities where landfills have more elaborate designs. Figures V-8 and V-9 summarize the costs of the Proposal as a percentage of community expenditures (CPE) for each of the three designs. The most severe impacts occur in the designs that include synthetic covers. Using the design goal at the 10-meter POC to assign designs, about 23 percent of the communities with landfills assigned synthetic covers and/or liners have CPE exceeding 1 percent. In fact, 6 percent of these communities have a CPE exceeding 2 percent. Of the communities with landfills with the unlined/vegetative design, 10 percent have CPE exceeding 1 percent, and only 0.4 percent exceeding 2 percent.

The same pattern holds true for CPE using the 150-meter POC. In this case only 9 percent of communities exceed 1 percent CPE with the unlined/vegetative design, but 25 percent of the unlined/synthetic and 19 percent of the synthetic/synthetic exceed the threshold. The landfills with the synthetic designs are also the ones that cause the highest average risk in the baseline.

Figure V-8

Cost as Percentage of Expenditures
By Design for Proposed Rule (10-Meter POC)

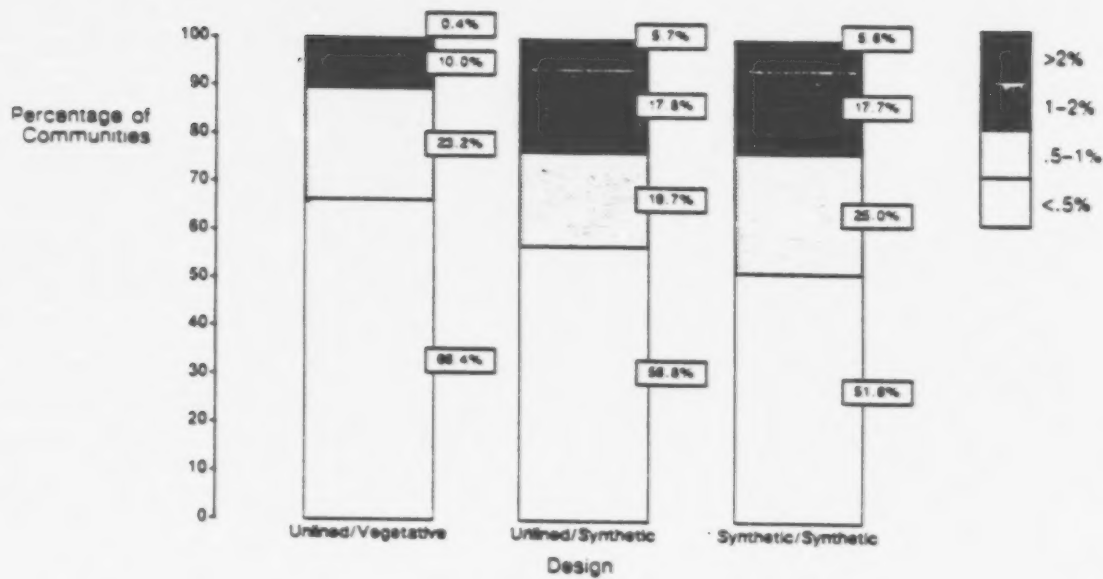
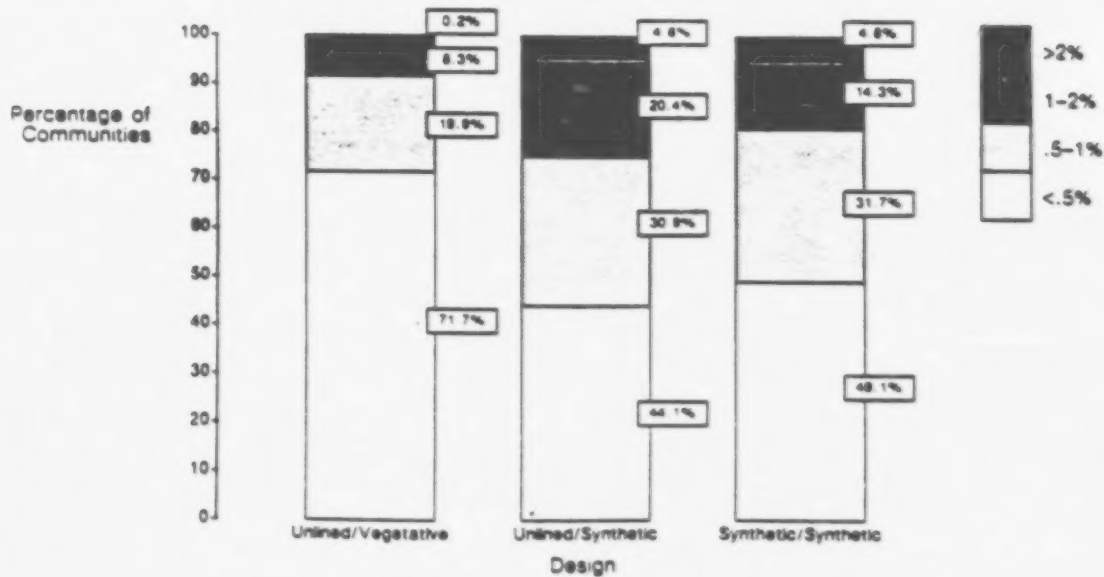


Figure V-9

Cost as Percentage of Expenditures
By Design for Proposed Rule (150-Meter POC)



Figures V-10 and V-11 show that the average annual cost per household (CPH) also varies significantly across the designs. A few communities served by landfills with synthetic/synthetic designs experience moderate impacts: costs exceed \$100 per household for 0.2 percent of communities if we use the 10-meter POC and for 2.1 percent using the 150-meter POC. The higher impacts resulting from the more distant POC are caused by the incidence of higher corrective action costs. The highest CPH for communities served by synthetic/synthetic design landfills is \$253; this occurs using the 150-meter POC.

The final measure of impacts, CPMHI, also varies by design, but within a fairly narrow range. No community in any of the three designs using the 10-meter POC exceeds the impact threshold of 1 percent. Only 0.5 percent of communities assigned to synthetic/synthetic landfills under the 150-meter POC exceed the impact threshold of 1 percent. CPMHI is less than 0.25 percent for both versions of the Proposal given the two unlined designs.

The impacts of the Proposal vary by state as well as by design. This pattern is most evident in the distribution of community CPH by state. Figure V-12 depicts those states where average CPH across communities tends to be either relatively high or relatively low as well as those states with a mixture of high and low costs. States where the average community CPH is greater than \$35 per year were classified as having higher costs; states where the average community CPH is lower than \$20 were classified as having lower costs. Because this information is based on a sample of landfills, rather than on all landfills in each state, it should be interpreted cautiously.

With the exception of Alaska, all the states with higher costs are located in the Northeast. There are several reasons why this group of states tends to have higher costs. The New England states, New York, and Wisconsin are all characterized by large numbers of relatively small landfills. Because the costs of the Proposal exhibit pronounced economies of scale, communities that are served by smaller landfills tend to have disproportionately high costs. Landfills along the Atlantic coastal plain are also more likely to fall into the synthetic/synthetic design because many parts of this region are characterized by higher precipitation and relatively short times of travel through the unsaturated zone.

The differences between the two versions of the Proposal are quite small. The higher corrective action costs for the Proposal using the 150-meter POC push Hawaii into the high category, but Connecticut, Georgia, Mississippi, and Tennessee fall to the next lower category of CPH.

Figure V-10
 Cost per Household per Year
 By Design for Proposed Rule (10-Meter POC)

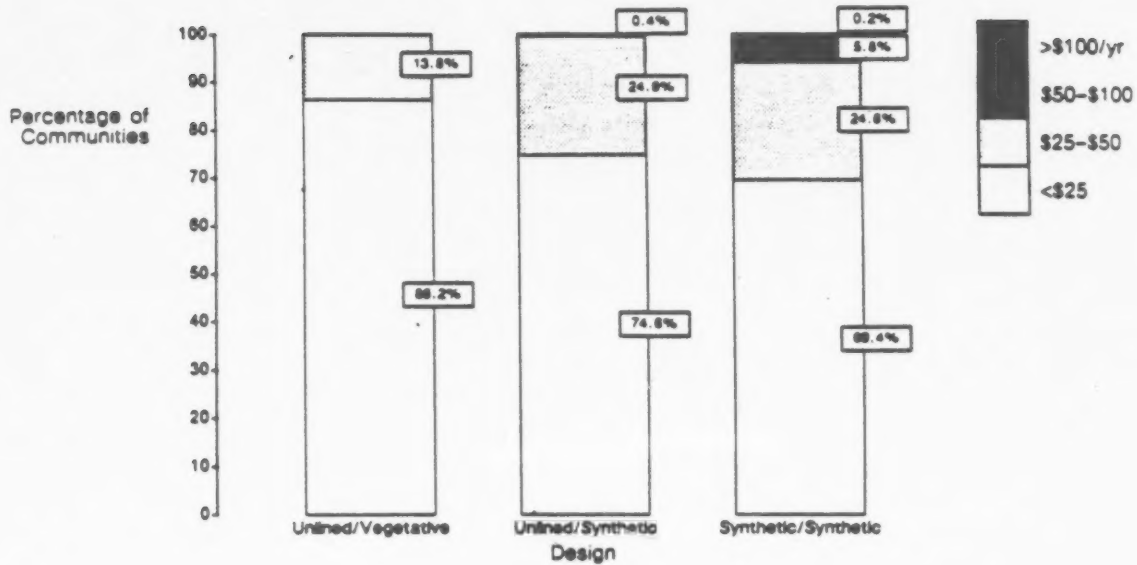


Figure V-11
 Cost per Household per Year
 By Design for Proposed Rule (150-Meter POC)

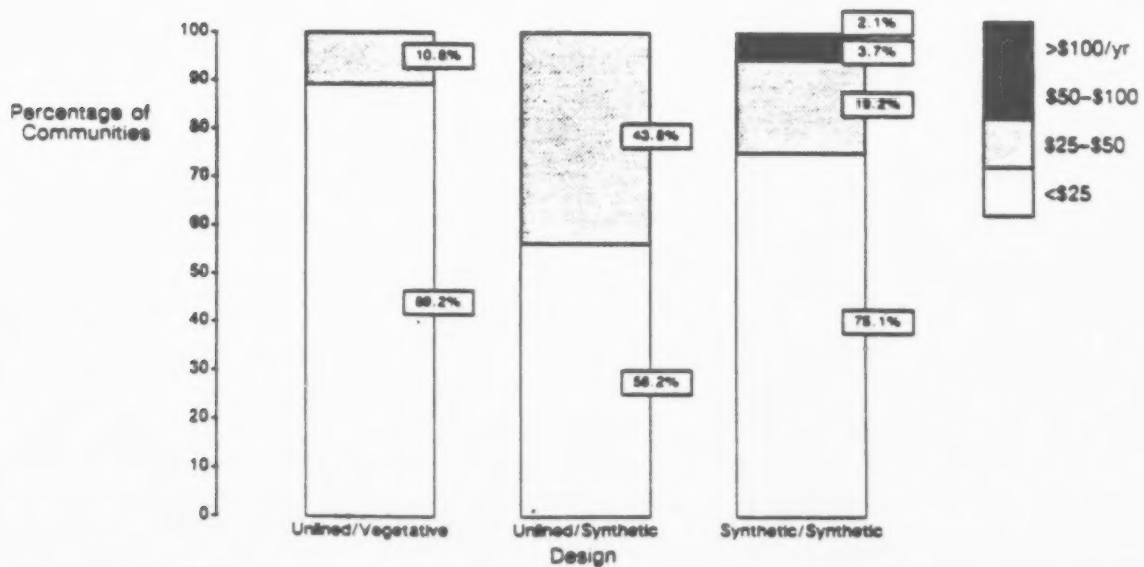


Figure V-12
Average Community Costs per Household by State
for the Proposal (10-Meter POC)



Impacts on households also depend on who owns the landfill that serves those households. Table V-30 indicates the number of communities and landfills by each major ownership category--county, city, village or town, private, and other. (The other category covers landfills owned by non-local governments including special districts, states, and the federal government.) The distribution of communities by ownership type looks somewhat different than the same distribution of landfills because county-owned and private landfills tend to serve a larger number of communities than city or town landfills. The table clearly indicates that communities served by village or town landfills have much higher CPH than average. These landfills tend to serve only one or two communities and are commonly very small, thus the higher CPH. Communities served by private landfills, on the other hand, have lower than average CPH. These landfills usually serve many communities and tend, on average, to be larger than publicly owned landfills.

Table V-30

NUMBER OF COMMUNITIES AND LANDFILLS BY TYPE OF OWNER: PROPOSED RULE

Owner	Communities		Landfills		Average Number of Communities per Landfill	Average Community Cost per Household	
	Number	Percentage	Number	Percentage		10-Meter POC	150-Meter POC
County	10,618	37%	1,760	29%	6.0	\$18	\$13
City	6,622	23	1,743	29	3.8	16	15
Village or town	2,115	7	1,182	20	1.8	34	31
Private	8,556	30	912	15	9.4	10	10
Other	1,087	4	427	7	2.6	15	15
Total	28,998 ^a	100% ^b	6,024 ^a	100% ^b	4.8	\$16	\$14

^aData are missing for 10 landfills in 19 communities.

^bTotals may not add to 100 percent because of rounding.

Comparison of Regulatory Alternatives

The discussion of the three regulatory alternatives focuses on the numbers of communities that exceed the threshold levels of each of the three economic impact measures. Impacts are highest under Alternative 1 and lowest under Alternative 3, regardless of which impact measure is used. The impacts of the Proposal are also briefly summarized below to facilitate comparison with the alternatives.

Table V-31 indicates the percentage of communities and people whose CPE will exceed 1 percent under the Proposal and each of the three alternatives. Under Alternative 1, more than two-thirds of communities have CPE exceeding 1 percent, while under Alternative 2, 33 percent of all communities fall in this category. The percentage of municipalities with costs above 1 percent of current expenditures under the Proposal is much lower: 16 percent and 11 percent, given the 10-meter POC and 150-meter POC. Because most of these communities are small, the percentage of total U.S. population that resides in these communities is much smaller than the percentage of communities affected.

The maximum CPE for any community under the Proposal (10-meter POC) is 4.0 percent. For the Proposal with the 150-meter POC, the maximum is 5.3 percent. Maximum CPEs for each alternative are 14.0 percent for Alternative 1, 6.3 percent for Alternative 2, and 8.6 percent for Alternative 3.

Using data from EPA's MSWLF survey, we estimate that the typical community currently spends approximately 0.5 percent of its budget on solid waste disposal. For many communities, the incremental costs of complying with these regulatory options will exceed 1 percent of their current expenditures, a 200 percent increase in their solid waste disposal costs.

Table V-31

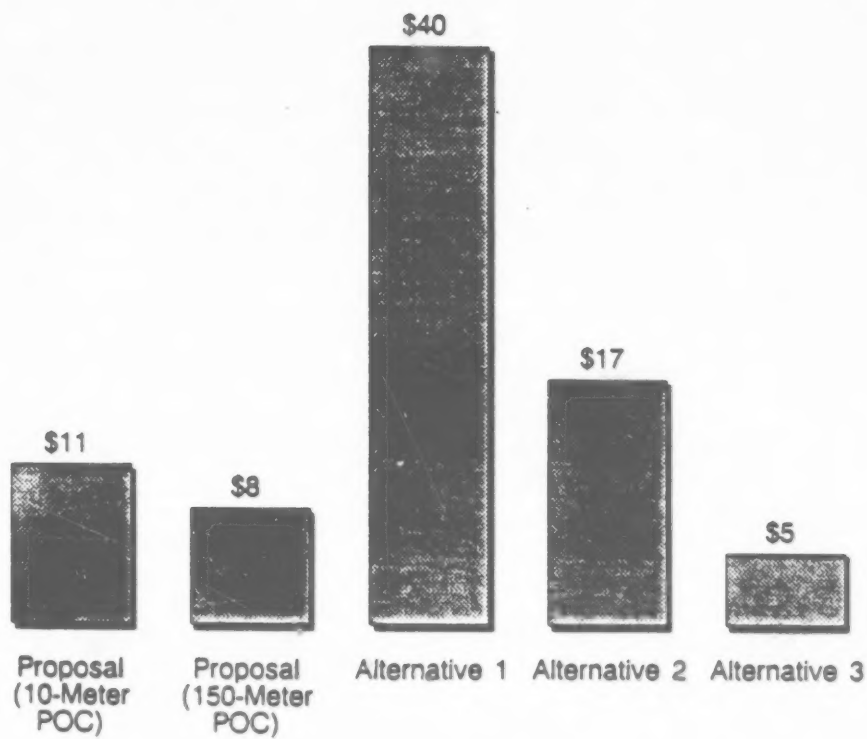
MUNICIPALITIES AND PEOPLE WITH REGULATORY
COSTS EXCEEDING ONE PERCENT
OF CURRENT EXPENDITURES

Regulatory Option	Municipalities		People	
	Number	Percentage of Total	Number (millions)	Percentage of Total
Proposal (10-Meter POC)	4,742	16%	15.5	7%
Proposal (150-Meter POC)	3,293	11	9.6	4
Alternative 1	19,661	68	79.5	34
Alternative 2	9,491	33	28.7	12
Alternative 3	2,852	10	7.1	3

Source: TBS calculations.

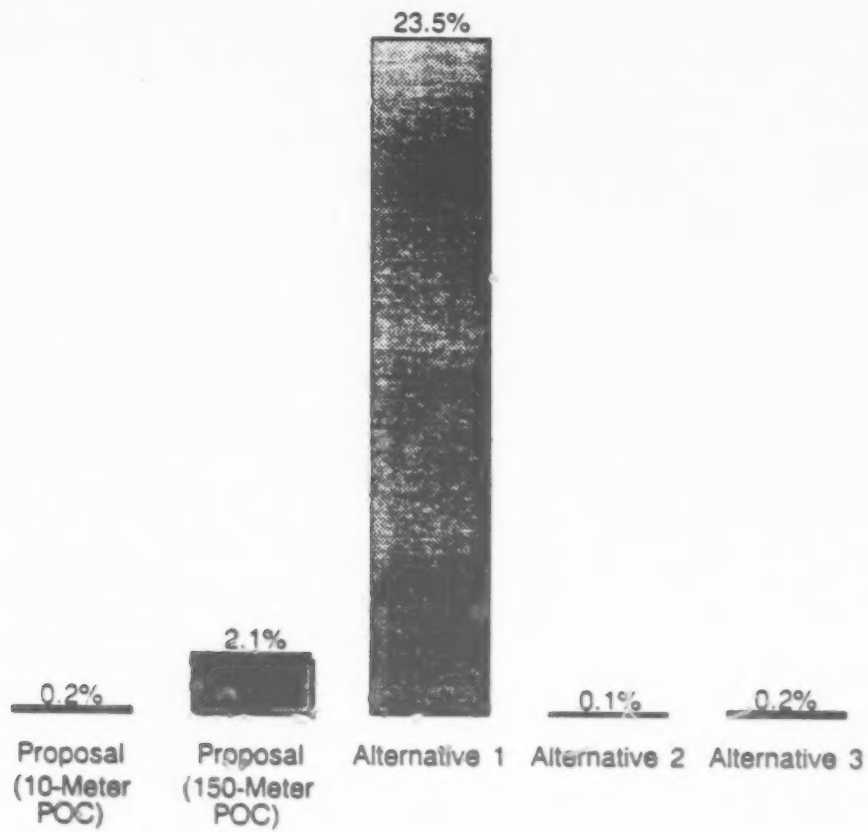
Figures V-13 and V-14 summarize the impacts of the regulatory options on households. Incremental CPH across the entire nation ranges from \$5 under Alternative 3 to \$40 under Alternative 1. Incremental CPH under the Proposal averages \$11 across all households if the 10-meter POC is used and \$8 if the 150-meter POC is in force.

Figure V-13
Average Incremental Cost per Household Across the Entire Nation
(dollars per year)



Source: TBS calculations.

Figure V-14
Percentage of Communities with Costs per Household
Exceeding \$100 per Year



Source: TBS calculations.

In the majority of communities, current solid waste disposal costs per household range from \$10 to \$30 per year (excluding collection and transportation costs), with fewer than 10 percent of all communities' CPH exceeding \$50 per year, according to the MSWLF survey. Thus, under the least expensive alternative, CPH will likely increase by 50 percent for many communities. As mentioned before, the reported costs in the survey may be too low because they may not include amortization of capital costs. As a result the percentage increase would be smaller.

The maximum cost per household projected for the regulatory options is as follows:

<u>Regulatory Option</u>	<u>Maximum CPH</u>
Proposal (10-meter POC)	\$119
Proposal (150-meter POC)	253
Alternative 1	335
Alternative 2	160
Alternative 3	178

For this analysis, the threshold level for severe impacts on households is \$220 per year. This threshold is exceeded under Alternative 1 and the Proposal using the 150-meter POC, but in both options, fewer than 1 percent of communities are in that category. Figure V-14 shows the percentage of communities where incremental CPH exceeds \$100. Only the Proposal (150-meter POC) and Alternative 1 have more than 0.2 percent of communities exceeding even this more moderate threshold. Under Alternative 1, 23.5 percent of the communities experience increases in CPH of more than \$100 per year.

Cost per household as a percentage of MHI only exceeds 1 percent under the Proposal (150-meter POC) and Alternative 1. EPA's construction grants program uses a threshold of 1 percent for this measure to identify communities that might experience difficulties affording new wastewater treatment facilities. In our analysis, 1.1 percent of communities exceeded the threshold under Alternative 1 and less than 0.1 percent exceeded it under the Proposal using the 150-meter POC. The maximum CPMHI for any community was 1.7 percent under Alternative 1 and 1.3 percent under the Proposal (150-meter POC).

Baseline Financial Capability

The first step in the municipal financial capability analysis is to assess the current financial health of local governments by calculating a composite financial rating or score.

This score combines information on communities' current revenue, expenditures, debt, and demographic characteristics into a single point estimate of financial capability. Based on this measure, we classified communities as strong, average, or weak financially.¹ Twenty-seven percent of all communities were classified as strong, 49 percent as average, and 24 percent as weak.

Weak governments, which typically have relatively high levels of debt and expenditures, low income, and a high fraction of the population below the poverty level, might have difficulty coping with even moderate increases in expenditures for solid waste disposal. Strong communities, on the other hand, typically have the economic base and flexibility in their budgets to accommodate all but the most severe levels of economic impact.

The baseline results presented below are calculated on all 29,017 government jurisdictions contained in the database described in Chapter IV. The actual analysis of impacts was conducted on the subset of 1,810 of these communities that are served by the landfills that responded to the MSWLF facility survey. Comparison of financial capability scores for the subset and the entire database indicates that the sample of communities included in the analysis is representative of both the size and financial health of the entire population of local governments. As Chapter IV describes, the results of the economic impact analysis on this subset of communities were also weighted based on community size and financial capability to compensate for any minor differences between the characteristics of the sample and the characteristics of all local governments.

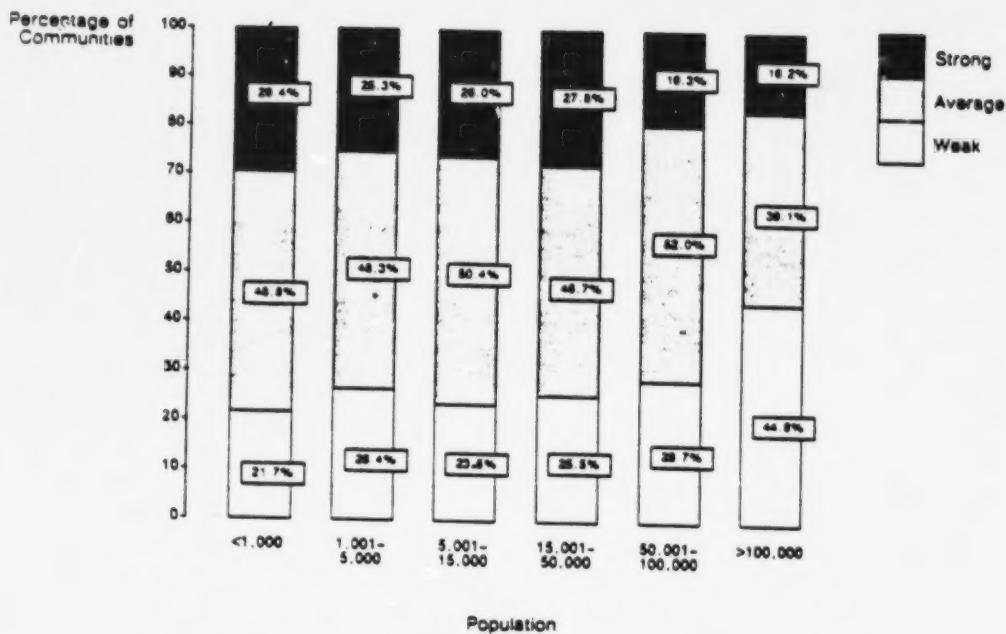
If we look at the total number of governments that are relatively weak (6,973), 75 percent of them are small (less than 5,000 people), so the majority of weak governments are also small. This pattern, however, reflects the same distribution in the entire sample, that is, 77 percent of all 29,017 governments are small.

Figure V-15 summarizes the relative financial capability ratings for all governments by the population they serve. It displays the percentage of governments that are classified as strong, average, or weak in each of the population size categories. The chart shows that larger governments are more likely to be classified as weak than smaller ones. Small communities' ratings differ, however, depending on whether or not they are located in rural areas. We will address this below.

¹The score can take on any value from 1 through 5. Communities with scores of less than 2.6 were characterized as weak; those with scores greater than 3.2 as strong; and the remainder as average.

Figure V-15

Financial Capability Rating for Governments By Size Categories



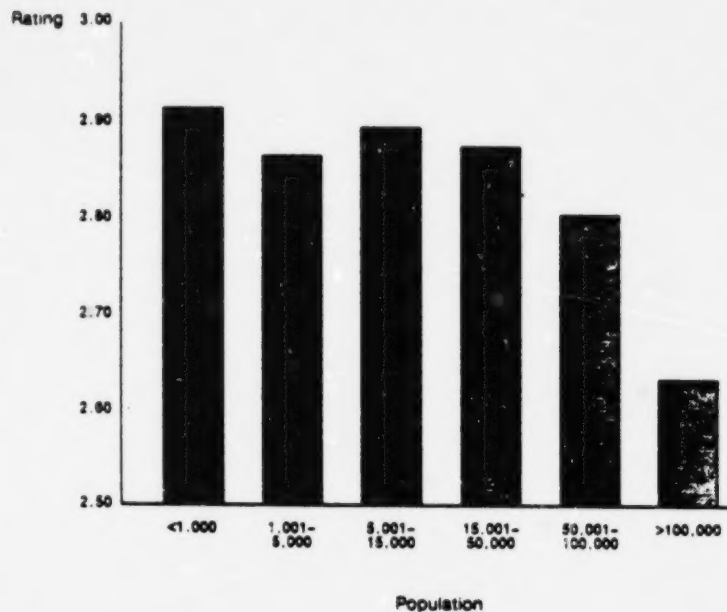
Source: TBS calculations.

Figure V-16, which summarizes the average financial capability rating for each size category, shows this same pattern. Although the average financial capability score for all population sizes falls into the "average" category, communities with fewer than 1,000 people have the highest scores, and those serving more than 100,000 people the lowest.

For the largest communities (primarily cities over 100,000 people), the financial scores are often quite low because these communities have a different type of government that provides services to large numbers of people who work or live in the community. Thus, these governments usually spend more and incur more debt per person than smaller jurisdictions. The pattern of small communities' spending is also different. Smaller communities, for example, issue a much lower percentage of debt to finance utility expenditures such as water, electric, or transit

services than do larger communities. Larger cities are also more likely to have low MHI and many are losing population to neighboring suburbs, both factors that would tend to lower their financial scores.

Figure V-16
Average Financial Capability Rating for Governments
By Size Categories



Source: TBS calculations.

The financial capability scores across community sizes tend to fall in a fairly narrow range around the average score of 2.89, with few exceptions. Within these community sizes, however, the financial capability scores differ between rural and urban communities. Small communities especially are split between those that are in rural areas and those that are suburban (i.e., associated with a neighboring urban area). We expect that the financial capability score of rural small towns will be lower than for suburban communities. The rural/urban split was defined by population densities with 40 people per square mile as the

cutoff (mid-way between the national average of 64 and the average of "rural America" of 17 people per square mile defined by the Statistical Abstract.² Ninety-two percent of rural communities have populations less than 5,000.

Figure V-17 shows that for the smallest communities, rural towns are much weaker than suburban towns with a rating of 2.8 versus 3.1. The difference is less pronounced for communities of between 1,000 and 5,000. From these results we expect small rural communities to be adversely affected by the regulations more often than small suburban communities.

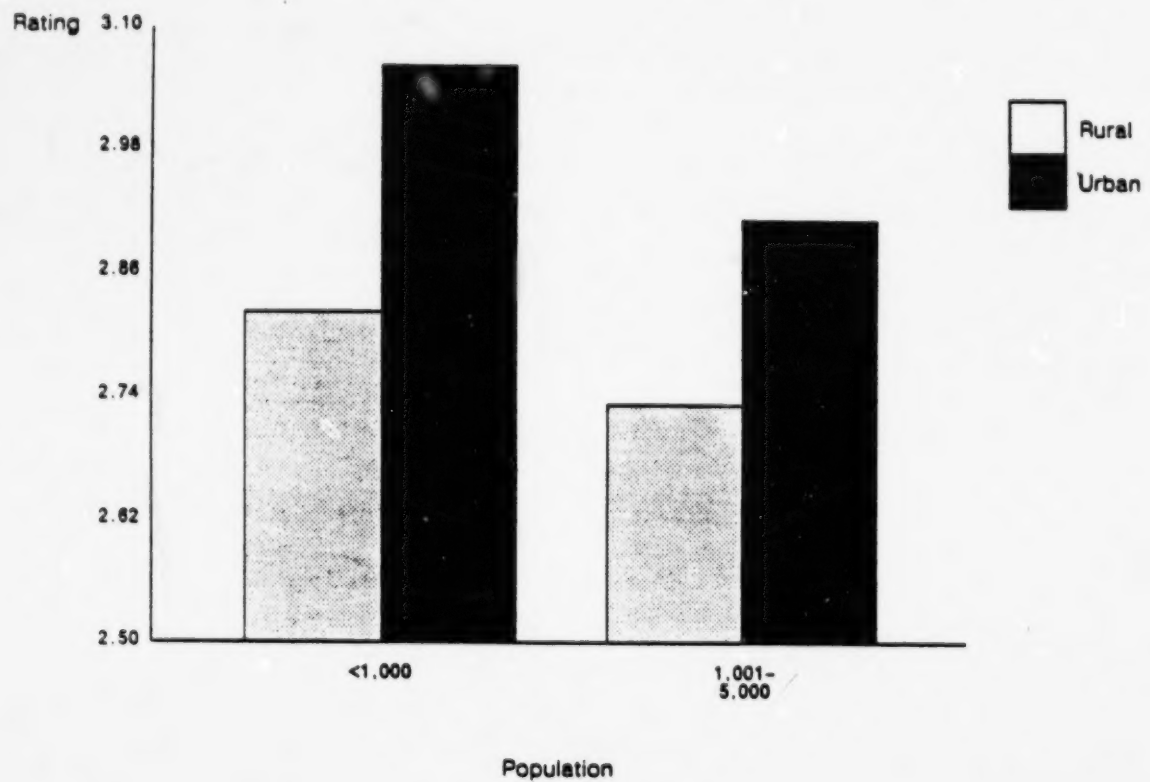
Impacts and Financial Capability

The financial capability baseline discussed above enables us to investigate whether communities that incur relatively high costs as a result of the Proposal are weak or strong financially. Figures V-18 and V-19 present the distribution of CPE by communities' financial capability score. The figures show that weak communities are somewhat less likely to face large increases in expenditures than strong communities. Using the 10-meter POC, CPE exceeds 1 percent in 22 percent of all strong communities, 16 percent of all average communities, and 11 percent of all weak communities. The same pattern emerges using the 150-meter POC; CPE is greater than 1 percent in 17 percent of strong communities, 10 percent of average communities, and 8 percent of weak communities.

The major factor accounting for these results is that a large community is more likely to be categorized as weak than a smaller community (even though in an absolute sense, small weak communities outnumber large weak communities). This is especially true for communities in urban areas where the smallest towns tend to have strong scores. The large communities in these areas are served by large landfills; because regulatory costs exhibit substantial returns to scale, these large (weak) towns are less likely to experience severe impacts. (The relationship between community size and economic impacts is discussed in more detail in the Regulatory Flexibility section of this chapter.)

²Statistical Abstract of the United States 1987, U.S. Department of Commerce, Bureau of the Census.

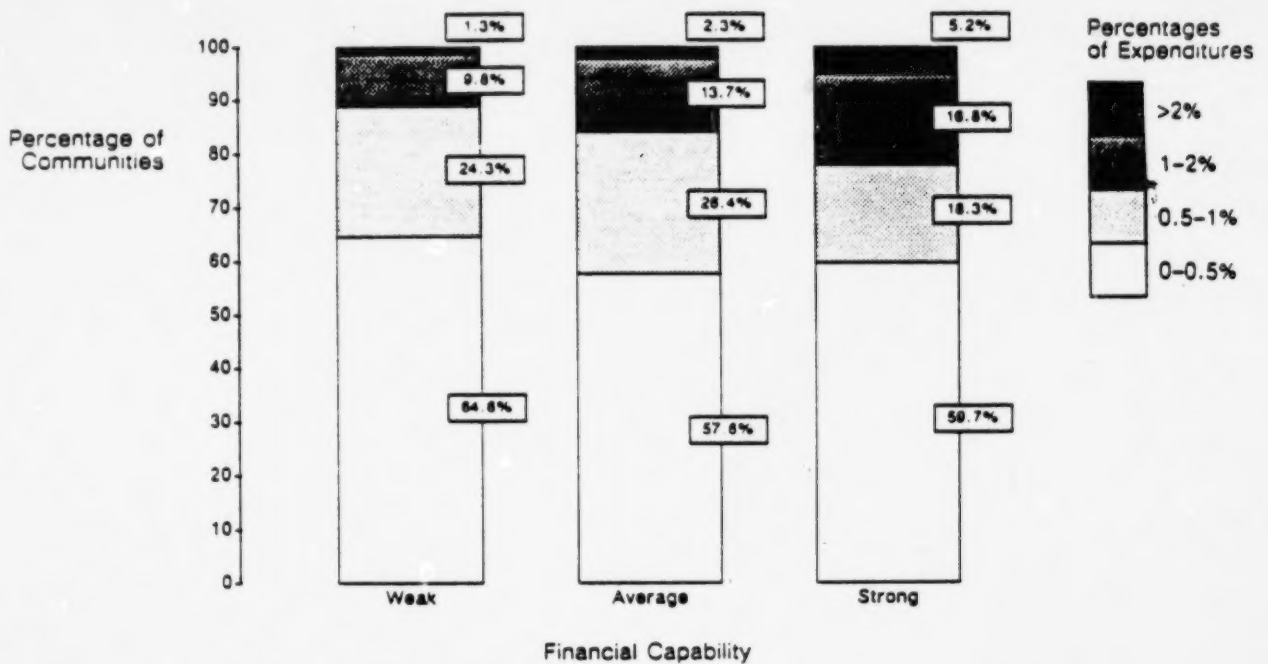
Figure V-17
Financial Capability Rating for Rural Versus Urban Areas
(All Communities Smaller Than 5,000 People)



Source: TBS calculations.

Figure V-18

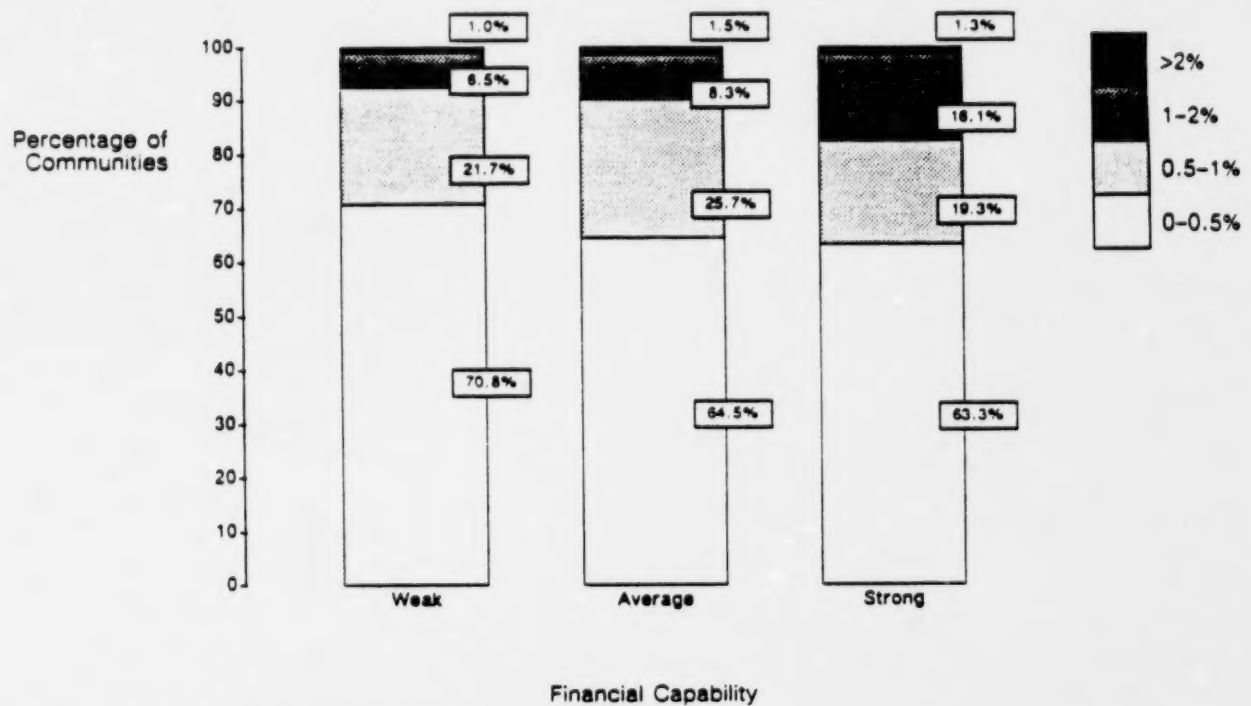
Incremental Cost as Percentage of Expenditures for Proposed Rule (10-Meter POC)
By Financial Capability Category



Source: TBS calculations.

Figure V-19

Incremental Cost as Percentage of Expenditures for Proposed Rule (150-Meter POC)
By Financial Capability Category



Source: TBS calculations.

The rural/urban split is also an important issue in the relationship between financial strength and impacts. For example, Figure V-18 showed that the Proposal (10-meter POC) resulted in severe impacts for 11 percent of weak communities. For rural communities only the fraction of weak communities with severe impacts is 18.4 percent, and the corresponding fraction for urban communities is only 4.7 percent. As we expected, rural communities dominate those with the highest impacts and weak financial capability.

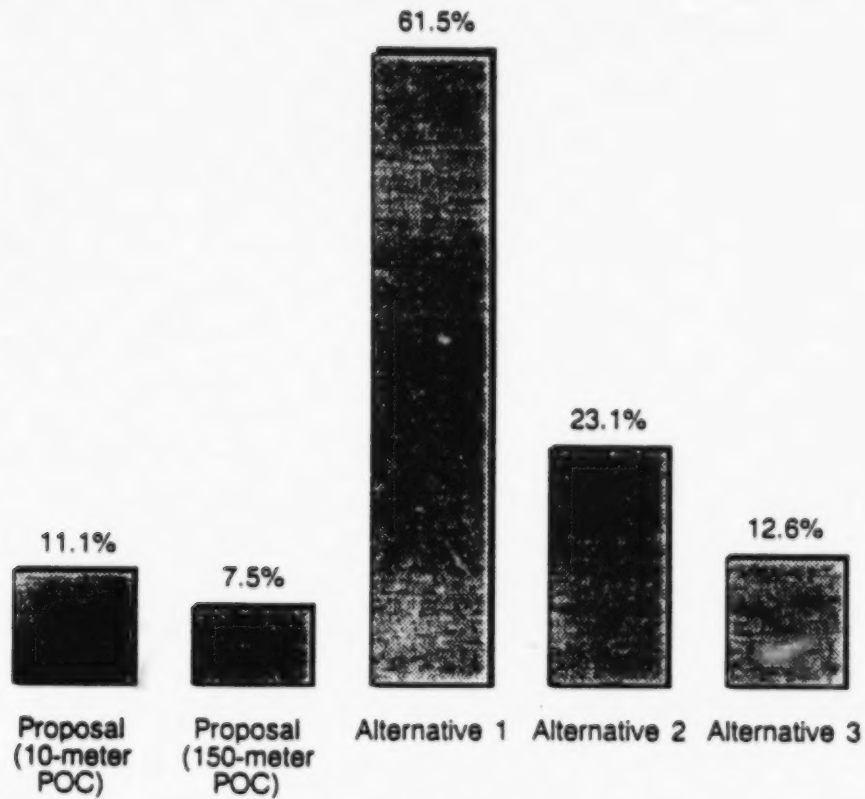
The two cost per household measures (CPH and CPMHI) indicate that these cost increases will not have a serious impact on the households served by these communities if we use the 10-meter POC, but using the 150-meter POC, a few high costs will exceed the thresholds in weak communities. About 0.3 percent of weak communities will incur CPH above \$220 and CPMHI above 1 percent; all of those communities are in rural areas.

Conclusions

The results of the economic impact analysis indicate that most of the options will impose significant impacts on at least some communities' expenditures for MSW disposal. Eleven percent of communities with weak financial capability will incur high CPE for complying with the Proposal at the 10-meter POC and 8 percent of weak communities will exceed the CPE threshold using the Proposal with an alternative POC. Figure V-20 shows that between 7.5 percent and 61.5 percent of the weak communities will exceed the CPE threshold of 1 percent, depending on the regulatory option. The Proposal (using either POC) has the lowest incidence of severe impacts on weak communities. Table V-31, however, indicates that although a large number of communities fall into the severe impact category for CPE, a far smaller percentage of the population is affected, because these communities tend to be the smaller ones.

All the options will impose at least moderate impacts on some households (CPH between \$100 and \$220). Only the Proposal with the 150-meter POC and Alternative 1 cause severe impacts but for fewer than 1 percent of all communities. CPMHI exceeds the threshold value of 1 percent for the same two options in 0.1 percent of the communities using the Proposal (150-meter POC) and 1.1 percent under Alternative 1. The absolute magnitude of CPH is quite low overall; for the vast majority (at least 99.6 percent for the Proposal) of communities, CPMHI is less than 0.5 percent.

Figure V-20
Percentage of Weak Communities with Costs
Greater Than 1 Percent of Expenditures
All Options



Source: TBS calculations.

Several factors will tend to mitigate the actual impact of the options on communities with high CPE. One important factor is the relatively small proportion of the municipal budget that is usually devoted to MSW disposal. Although CPE greater than 1 percent indicates that MSW disposal expenditures may double in many communities, even after regulation these expenditures will represent less than 2 percent of the total municipal budget in most communities. For comparison, the average community in the United States currently spends 36 percent of its budget on education, 5 percent for police protection, 3 percent for sewage disposal, 2 percent for fire protection, and 1 percent for sanitation services other than sewage, including solid waste collection and disposal and street cleaning (see Table IV-5). Although it may be difficult for communities to cope with large percentage increases in MSW disposal costs in the short run, once the initial adjustment is made, these costs should be easier for communities to absorb because they comprise a very small portion of communities' total budgets.

It is also important to recognize that the costs used in the economic impact analysis represent upper-bound estimates. Several opportunities for communities to reduce regulatory costs have not been factored into the analysis because they involve site-specific local decisions that are difficult to analyze. These opportunities include participation in larger, regional landfills that have lower incremental regulatory costs, shifts to resource recovery facilities in areas where this technology may become cheaper than building landfills that comply with new regulations, or--in the case of the Proposal--better siting of new landfills. For other communities that are located in states with more stringent regulatory requirements, they may face lower compliance costs because they already meet the proposed revisions to the landfill criteria. Finally, the cost model assumptions imply that communities set aside money during the operating life of the landfill to provide for post-closure care (i.e., post-closure compliance costs are paid from revenues generated during the operating life). Although private operators are likely to do this, publicly-owned landfills may have opportunities (depending on how financial responsibility requirements are met) to reduce impacts by deferring payment for post-closure care until the costs are actually incurred.

REGULATORY FLEXIBILITY ANALYSIS

Introduction

The Regulatory Flexibility Act requires federal regulatory agencies to determine whether proposed regulations will have a significant economic impact on a substantial number of small entities. When such impacts are identified, a regulatory flexibility analysis must be conducted prior to issuing a final rule to determine if small entities should be regulated in a different manner to reduce their economic burden. The Act is designed to identify regulations that will have adverse effects on small entities that are substantially greater than the effects on larger entities, and to require the regulatory agency to consider alternatives that will mitigate these differential impacts. This section analyzes the impacts of the proposed Subtitle D regulation on small governmental entities.

Definitions of Substantial Number, Small Entity, and Significant Impact

The Act and previous regulatory flexibility analyses provide some guidance in developing definitions of what constitutes a substantial number of small entities, what size criteria define a small entity, and what is a significant impact, although it allows EPA to develop a more appropriate definition if necessary. A "substantial number" for the purposes of the Act is typically defined as more than 20 percent of the affected population of small entities, although the absolute number of entities affected may also be considered. The Act provides an initial definition of small governmental entities as any government with a population of less than 50,000.

To determine how significant the impacts are, a number of measures have been used (e.g., compliance costs as a percentage of production costs; compliance costs as a percentage of sales; capital costs as a proportion of costs available; number/proportion of small entities likely to close). For each measure, a threshold value is assigned; when the threshold is exceeded, this constitutes a "significant impact."

Definitions of Substantial Number,
Small Entity, and Significant Impact
Appropriate for the MSWLF Analysis

We adopted the indicator/threshold approach to determine significant impact on small government entities. The indicators selected are those used in the economic impact analysis with the following thresholds:

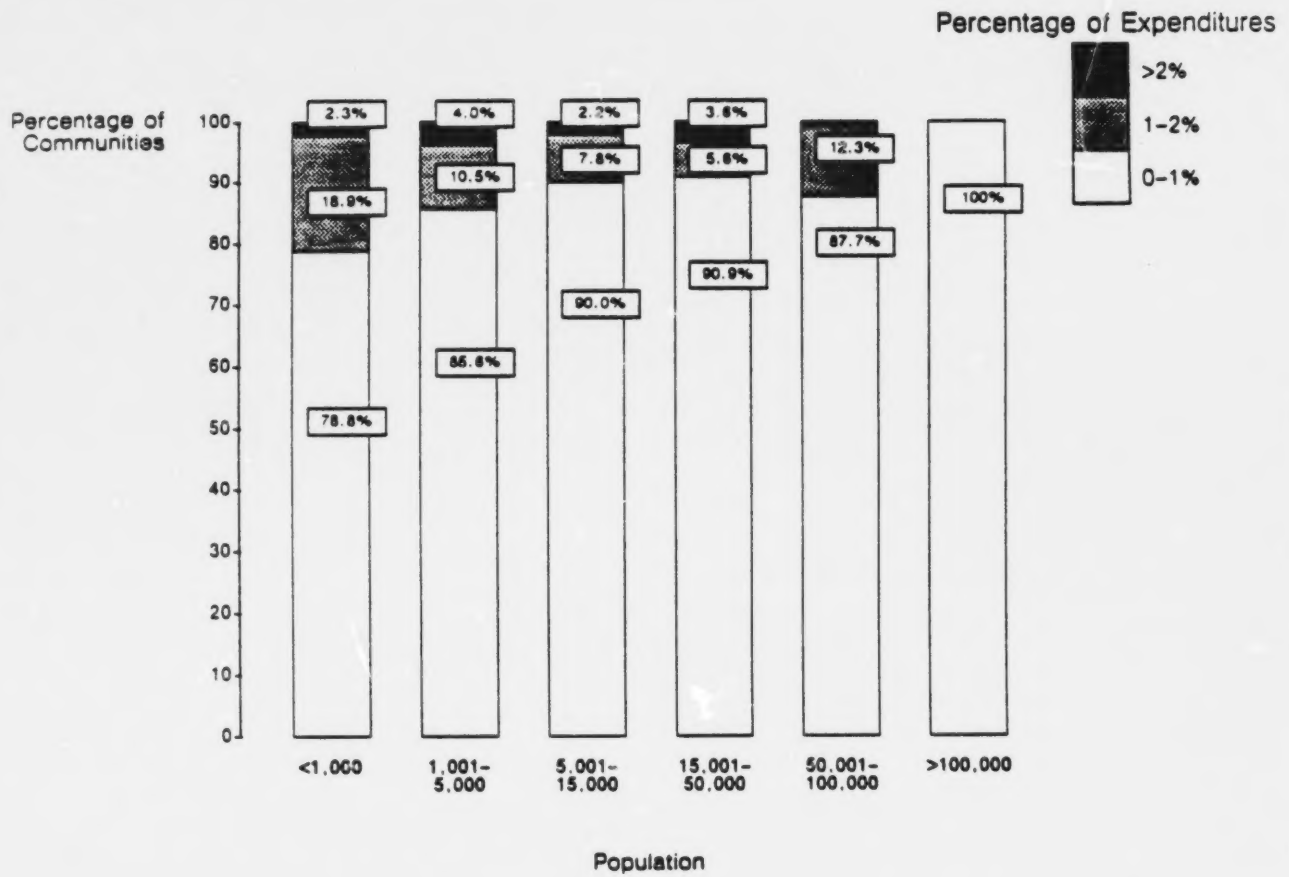
<u>Indicator</u>	<u>Threshold</u>
• Cost as a percentage of expenditures	1%
• Cost per household	\$220
• Cost as a percentage of median household income	1%

Figures V-21 and V-22 present data on cost as a percentage of expenditures and cost per household, both broken out by community size, for the proposed rule assuming use of the 10-meter POC. (The 150-meter POC is not analyzed because of its lower total costs. The pattern of impacts is very similar for cost as a percentage of median household income and is not displayed as part of this analysis.) The two indicators show similar patterns of impact with the greatest impacts falling on communities with populations of 5,000 or less. As described in the previous section of Chapter V, the small communities with a relatively weak financial capability tend to be located in rural settings. The threshold value for significant impact is only exceeded for the cost as a percentage of expenditures indicator. The municipalities exceeding the CPE threshold represent 16.5 percent of all municipalities. Eighty-six percent of these communities have populations of under 5,000 people.

The municipal database used in this analysis contains 29,017 entities; 97.6 percent of these entities have a population of 50,000 or smaller. Since such a large proportion of affected entities in our analysis meets the 50,000 population criterion suggested in the Act, and since impacts are greater on entities with less than 5,000 population, an alternative definition of a small entity is appropriate. There are 22,191 entities with populations of 5,000 or less; this represents 77 percent of the total. The proposed regulation will have its most severe impacts on governments serving less than 1,000 people, which include 46 percent of primary local governments. Therefore, an appropriate size definition for small entities for the purpose of a regulatory flexibility analysis falls somewhere between governments of 5,000 persons and 1,000 persons.

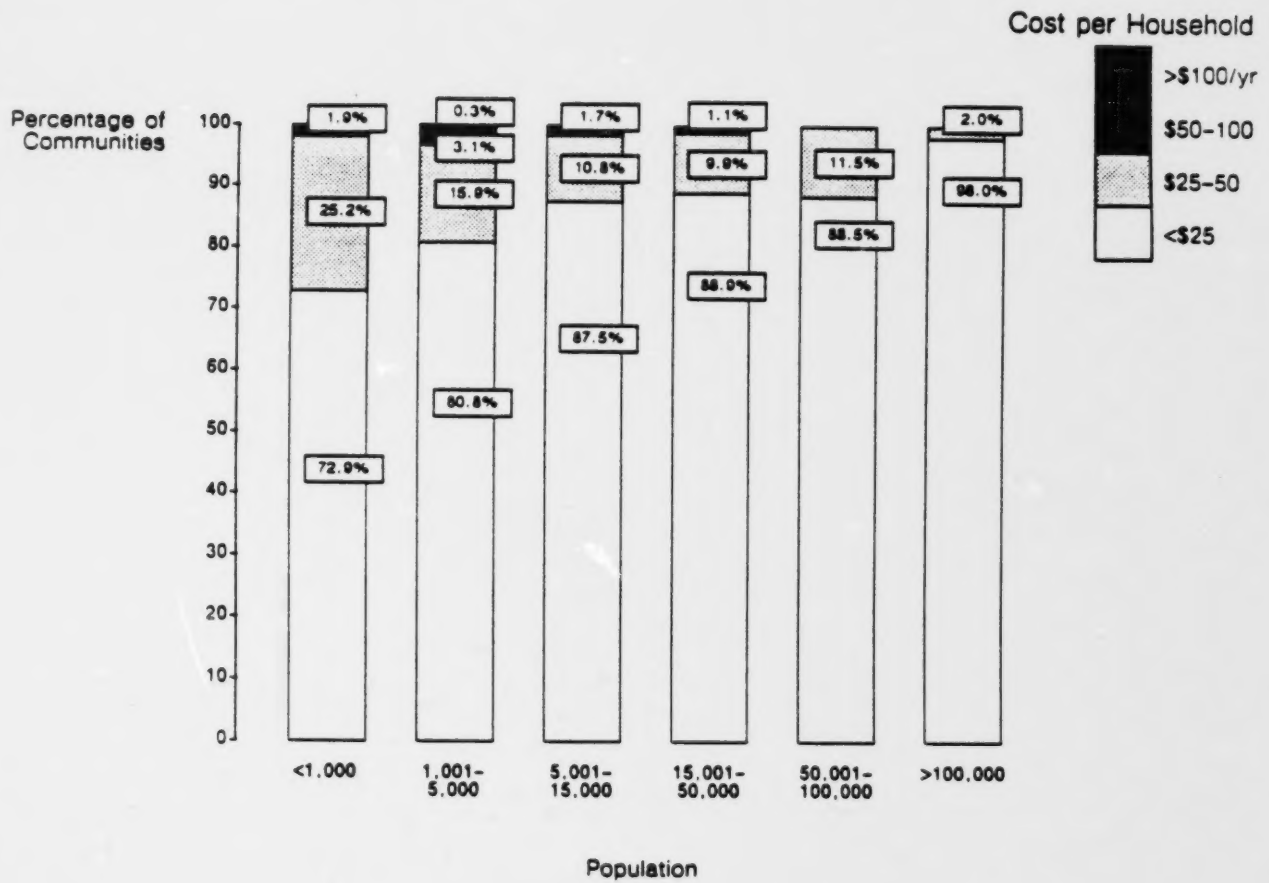
Figure V-21

Incremental Cost as Percentage of Expenditures for Proposed Rule (10-Meter POC)
By Community Size



Source: TBS calculations.

Figure V-22
 Cost per Household per Year for Proposed Rule (10-Meter POC)
 By Community Size



Source: TBS calculations.

One other group of small entities that will be affected by the regulation are the private landfill owners, who own 15 percent of all landfills as reported in the MSWLF survey. For these facilities, most will be able to pass regulatory costs on to the municipalities that they serve. However, in some cases, which are very difficult to predict, private owners will not be able to pass costs on and must absorb this extra cost or go out of business.

Due to the large cost increases over the analytical baseline costs, we have analyzed compliance costs as a percentage of baseline costs for private landfill owners relative to the size of their facilities. This was done to evaluate differential impacts on small versus large privately owned landfills. Since 64 percent of all private owners are projected to have a 20 percent or greater cost increase, a threshold value for significant impact was set at 40 percent. This is far above the 5 percent to 7 percent pre-tax profit levels for the industry reported by Robert Morris Associates. The potential cost increases above 40 percent are identified in Table V-32 for private owners.

Table V-32			
PERCENTAGE COST INCREASES FOR PROPOSED RULE (10-METER POC) ABOVE 40 PERCENT ¹			
Size TPD	Total	Above 40 Percent	
		Number	Percentage
0-17.5	346	52	15%
17.5-50	136	21	15
50-125	115	10	9
125-275	42	0	0
275-563	157	73	47
563-1,125	54	11	20
>1,125	37	8	20
Total	887	175	20%

¹For private landfill owners: compliance costs as a percentage of analytical baseline costs.

An underlying assumption in this analysis is that each small private landfill operates as an independent business (i.e., it is run by a small entity). While this assumption is not entirely correct, it is a good proxy for the impact on private owners, since large corporate owners of landfills will not continue to operate a landfill that is losing money just as a small business would cease operations if it were losing money. Similarly, small or large business landfill owners that also collect MSW may be willing to absorb landfill compliance costs against collection profits and would continue to evaluate their entire operations as an independent entity. In addition, for the purposes of the Regulatory Flexibility Act and the potential implementation of alternative criteria for small entities, it will be extremely difficult (based on available data) to distinguish between small businesses and businesses controlled by large corporations even though both entities run small landfills. For these reasons, we treat all small landfills as small entities for this preliminary regulatory flexibility analysis.

This table shows the clear potential for significant adverse impacts on private owners for all landfill sizes when costs cannot be passed through. Whether or not these impacts will ultimately fall on a substantial number of these entities will depend on each landfill's competitive position and ability to pass costs on to the landfill users.

Conclusion

This preliminary analysis of small entity impacts indicates that there are differential, although not significant, economic impacts on a substantial number of small governments. The impacts are more severe than those on large communities as measured by the indicators. The magnitude of the impacts are also dependent on the ability of landfill owners to pass costs through to customers.

It is less clear from this analysis if differential impacts observed are significant enough to warrant alternative regulatory requirements for small entities. These differential impacts will be assessed in greater detail in the final RIA.

RISK AND RESOURCE DAMAGE

In this section we present the results of the risk and resource damage analysis for the baseline, the Proposal, and each regulatory alternative. The risk results are discussed first, followed by the resource damage results.

Risk

As discussed in Chapter IV, we analyzed both 300-year average most exposed individual risk and population risk. In our discussion of average individual risk results below, we refer to four categories of risk: high, moderate, low, and very low. For this analysis, our operational definitions for risk categories are as follows:

- High--greater than 10^{-5}
- Moderate-- 10^{-6} to 10^{-5}
- Low-- 10^{-8} to 10^{-6}
- Very low--less than 10^{-8}

We emphasize that the risk categories are defined in this way for this analysis only, and do not represent Agency policy regarding high, moderate, low, and very low risk to individuals.

Baseline Risk

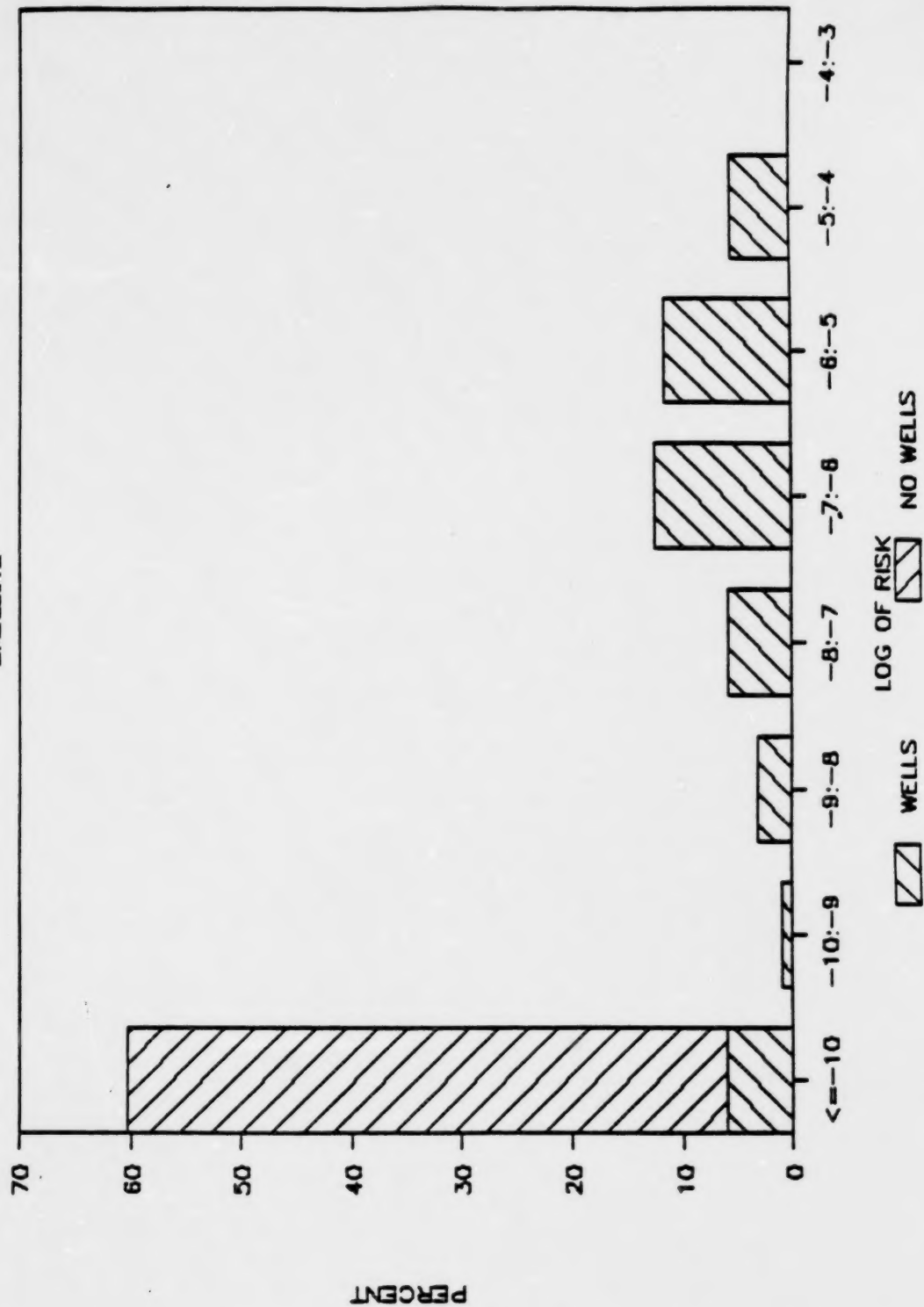
The baseline case assumes that all landfills are new, unlined, and, when closed, will be covered with topsoil and vegetation. In the following sections, we discuss the model outputs in terms of the overall distribution of risks and factors that influence the magnitude of risk to human health.

Distribution of Risk. Figure V-23 presents a frequency distribution of 300-year risk to maximum exposed individuals (MEIs) across all units. These results have been weighted by taking into account the relative frequency of net infiltration, water table depth, hydrogeologic flow settings, landfill size, and distance to the nearest ground-water well. The height of each bar in Figure V-23 indicates the proportion of landfills modeled where risks fall into a given range (e.g., 10^{-7} : 10^{-6} means that risk is greater than 10^{-7} and less than or equal to 10^{-6}). A risk of 10^{-6} indicates that exposed individuals would

Figure V-23

DISTRIBUTION OF AVERAGE RISK

BASELINE



bear a 1 in 1,000,000 increased chance of contracting cancer in their lifetime as a result of the exposure.

The figure shows that risks range from zero to about 1×10^{-4} . Over 54 percent of landfills have no nearby wells (i.e., no wells within 1,600 meters of the facility boundary, as reported in the MSWLF survey) and hence have no modeled human health risk. Another 6 percent have nearby wells but have no risk because constituents do not reach the wells within the modeling period. Risks are low (10^{-6} to 10^{-8}) or extremely low (less than 10^{-8}) for a total of 82.8 percent of landfills. Of the remainder, 11.6 percent have moderate risk (i.e., fall into the 10^{-6} : 10^{-5} range), 5.5 percent have high risk (10^{-5} : 10^{-4}), and a negligible 0.05 percent exceed 10^{-4} . The principal constituents contributing to risk are vinyl chloride; 1,1,2,2-tetrachloroethane; and dichloromethane (methylene chloride). While arsenic is the primary constituent of concern in some environmental settings, risks for these settings rarely exceed 10^{-6} .

Another way to portray baseline risk is in terms of a cumulative distribution, as presented in Figures V-24 and V-25. The y-coordinate for any point on these graphs corresponds to the percentage of landfills with risks exceeding the point's x-coordinate. Figure V-24, the cumulative distribution for all landfills, shows that the median risk (the point at which half the landfills have higher risks and half have lower risks) is zero. This result is obvious since over half the landfills have no nearby wells. The figure further shows that less than 20 percent of landfills have a risk greater than 10^{-6} .

When we consider only landfills that have nearby wells (Figure V-25), a somewhat different picture emerges. For this subgroup of the population, the median risk is about 4.3×10^{-7} . In addition, nearly 40 percent of the landfills have a risk exceeding 10^{-6} . This distribution has important implications because as more landfills shift into this subgroup (the result of new wells being drilled or new landfills being located near existing wells), the risks for all landfills will tend to approach this distribution.

We predict about 0.0770 expected cancer cases per year over the 300-year modeling period.

Factors Affecting Baseline Risk. Risk from municipal landfills varies depending upon the size of the landfill, the distance to the nearest ground-water well, and the environmental setting, including net infiltration rates, water table depth, and flow field type. In this section of the report, we examine how these factors affect risk. In order to focus on the impact of

Figure V-24

CUMULATIVE FREQUENCY OF AVERAGE RISK

BASELINE - ALL LANDFILLS

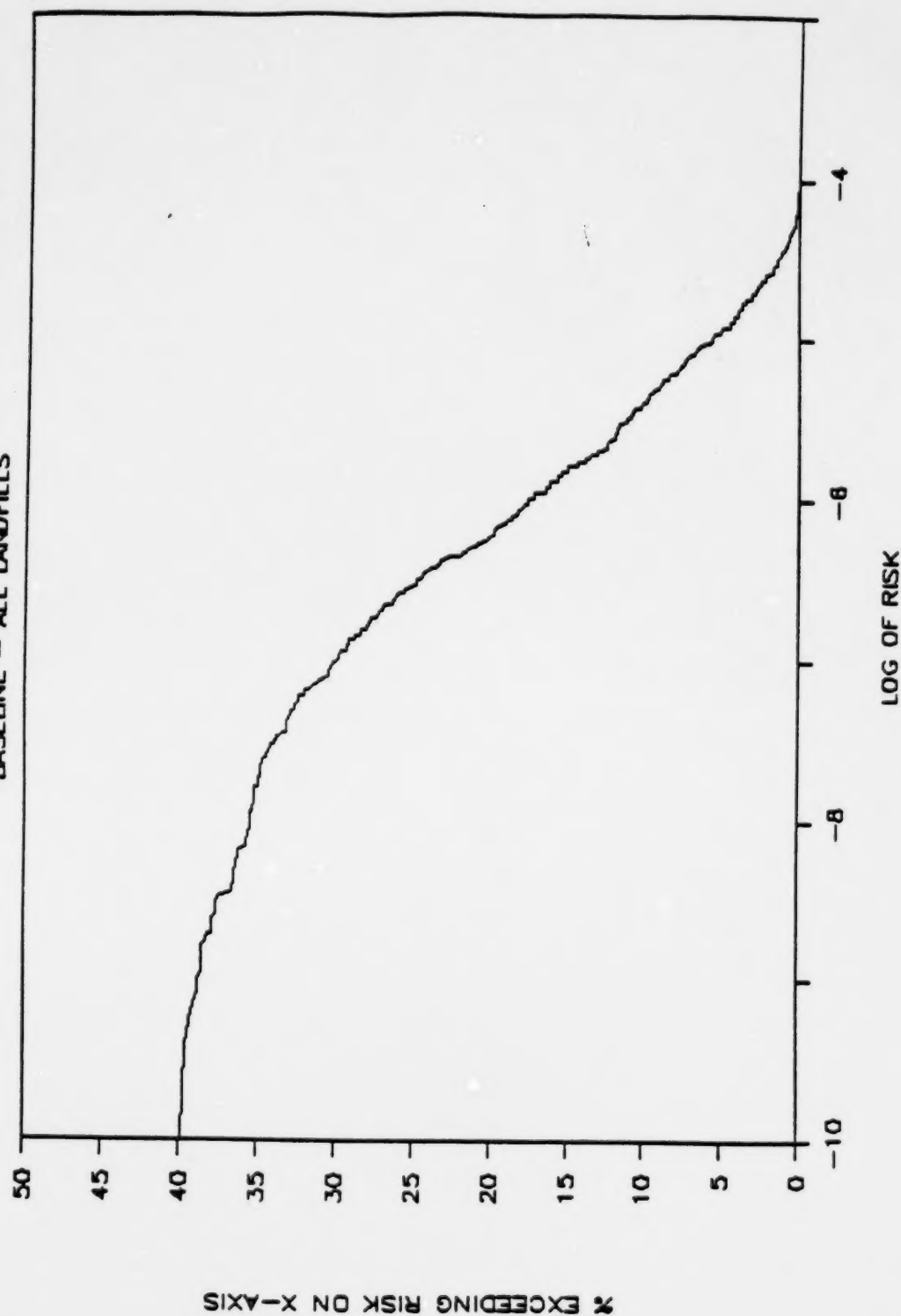
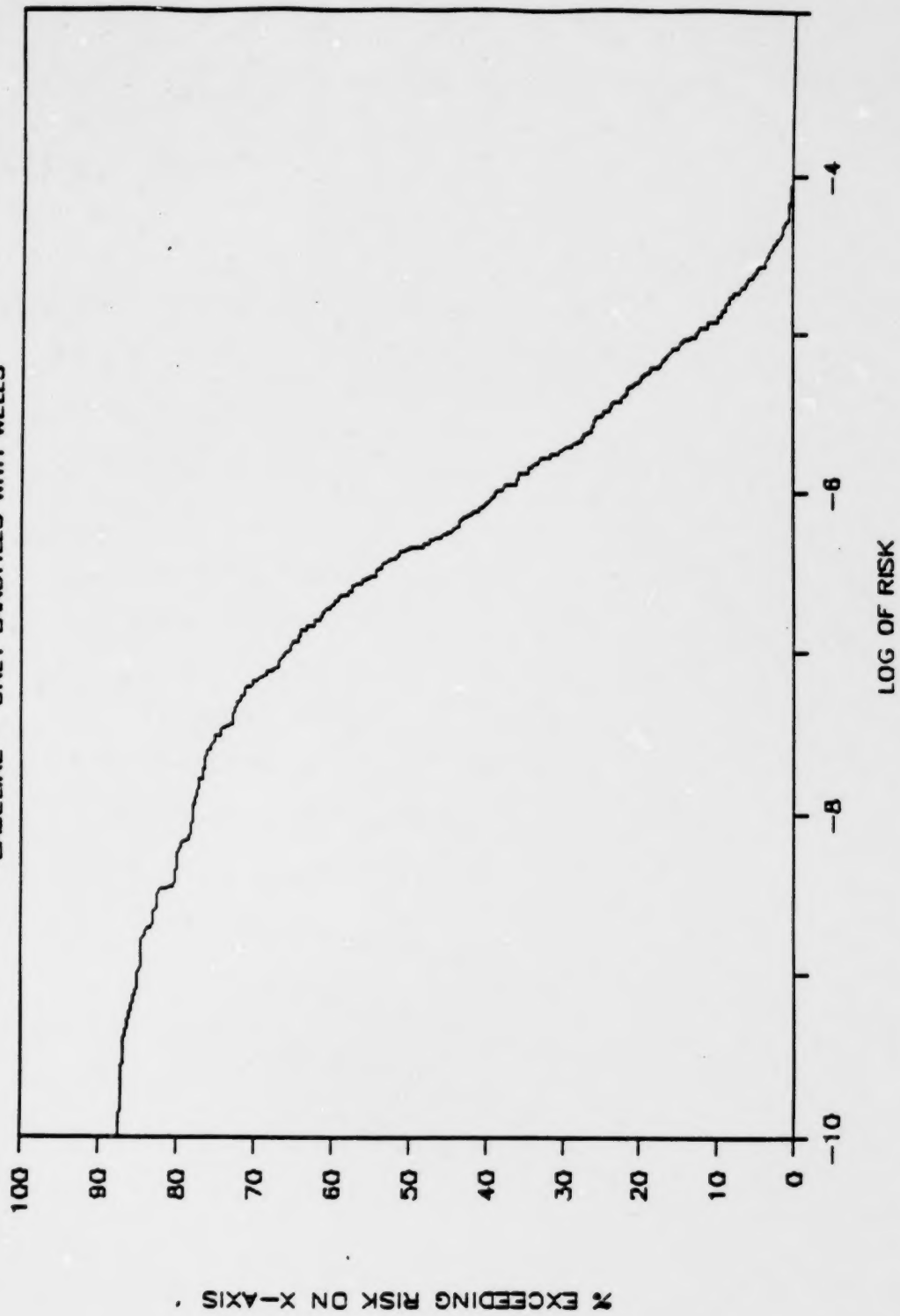


Figure V-25

CUMULATIVE FREQUENCY OF AVERAGE RISK

BASELINE — ONLY LANDFILLS WITH WELLS



each factor, the results are presented in unweighted terms (i.e., each landfill size/environmental setting/well distance combination is weighted equally).

- Facility Size. As Figure V-26 shows, facility size is an important determinant of risk. Higher levels of contamination and hence higher risks are associated with larger facilities which have a greater mass of waste. In 10-TPD facilities, about 33 percent of the scenarios have risks that exceed 10^{-6} . This value increases to over 55 percent for 175 TPD and nearly 64 percent for 750 TPD. Eight percent of the 10-TPD scenarios have risks exceeding 10^{-5} , 22 percent of the 175-TPD scenarios exceed 10^{-5} , and nearly 30 percent of the 750-TPD scenarios exceed 10^{-5} . Since only 5.5 percent of landfills fall into the 750-TPD category, the impact of these landfills on the overall distribution is small. The small (10-TPD) facilities account for almost 62 percent of landfills; their lower risk profile tends to "pull" the overall distribution toward the low side of the risk spectrum.
- Distance to Nearest Well. All other factors held constant, risk decreases with distance from the facility. Contaminant concentrations diminish over distance due to degradation, dispersion, and attenuation, as shown in Figure V-27. At 10 meters, over 67 percent of the settings have risks exceeding 10^{-6} ; 34 percent exceed 10^{-5} . On the other hand, only about 2 percent have very low risk. At 1,500 meters, only 40 percent of the scenarios have risks exceeding 10^{-6} and almost 15 percent have very low risk (less than or equal to 10^{-8}).

The influence of well distance on the overall risk distribution depends on the relative weights assigned to each distance. The fact that over 54 percent of landfills have no nearby wells (i.e., within 1,600 meters) sharply diminishes overall risk. Only 3 percent of the landfills have their closest wells within 35 meters; 12 percent have wells between 35 meters and 300 meters; 12 percent have a well in the 300 to 500 meter range; and the remaining 20 percent have closest wells between 500 and 1,600 meters. While the closest wells have the greatest risk, their occurrence is relatively rare, and their impact on the overall risk distribution is consequently small.

In Figure V-28, we compare the cumulative frequency of average risk assuming that exposure occurs: (1) at the actual exposure well distribution, (2) at the unit

Figure V-26
DISTRIBUTION OF AVERAGE RISK - BASELINE



Figure V-27

DISTRIBUTION OF AVERAGE RISK - BASELINE

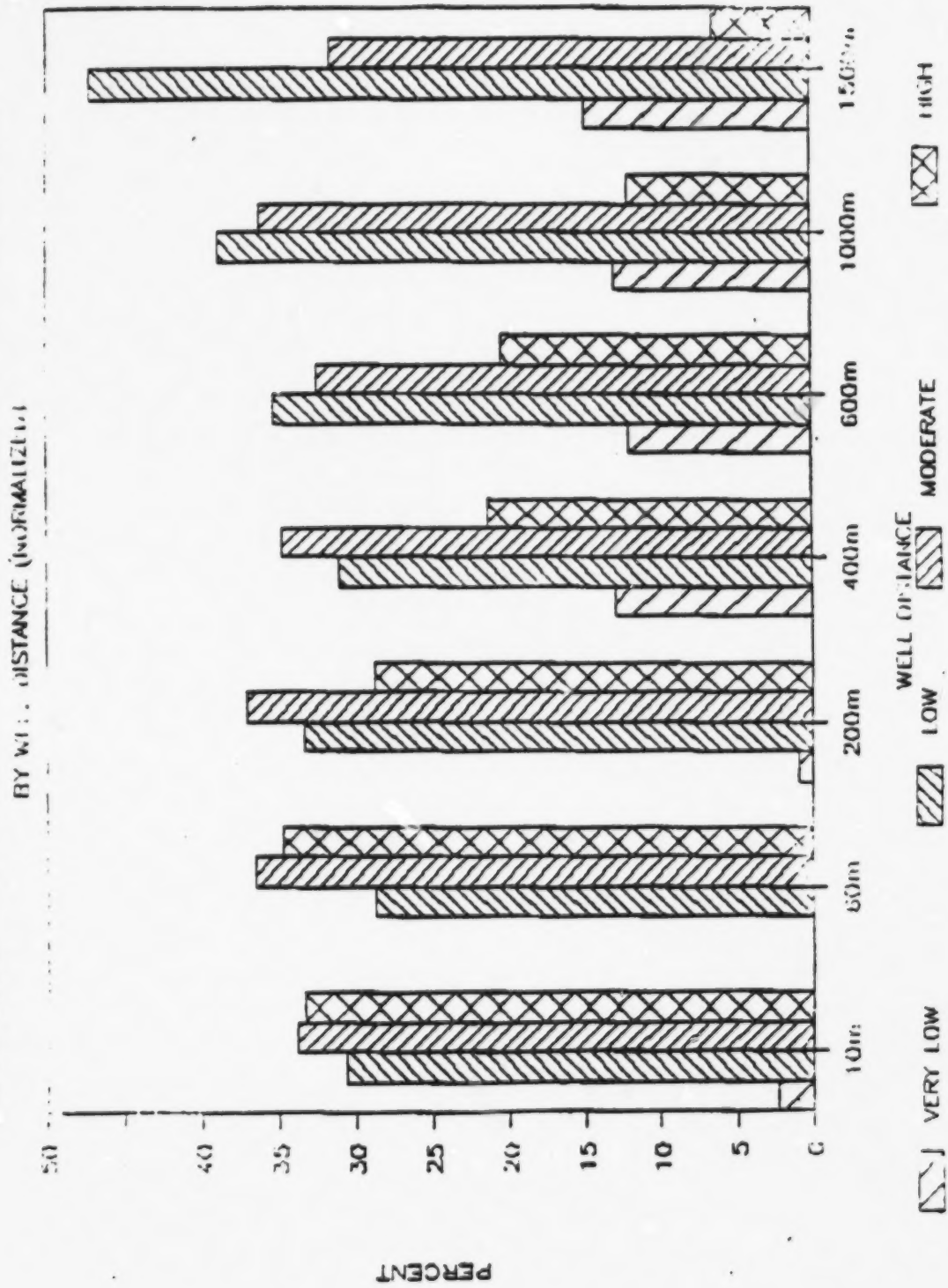
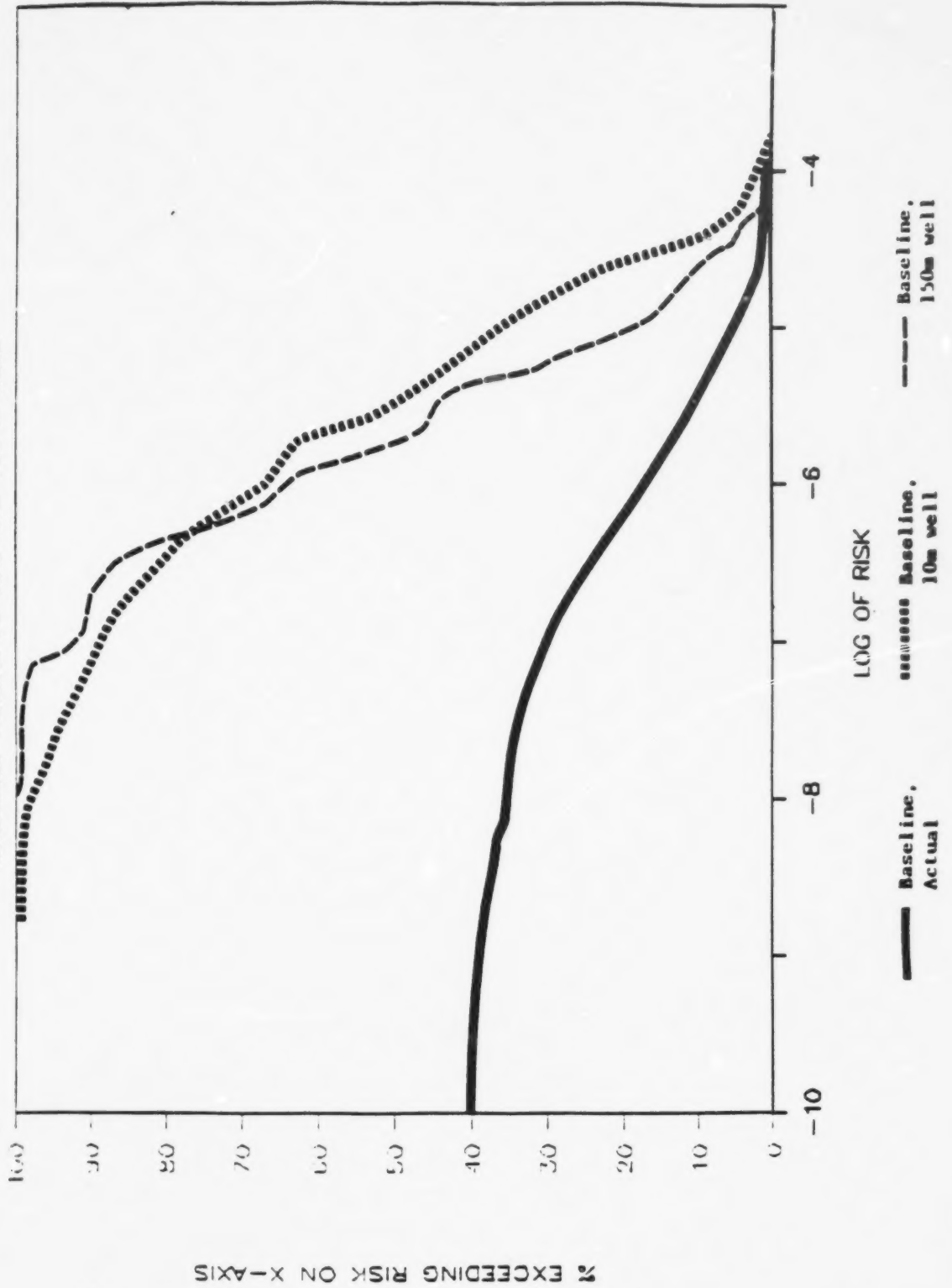


Figure V-28

CUMULATIVE FREQUENCY OF AVERAGE RISK

BASELINE—ACTUAL VS 10M AND 150 M WELL



boundary of all landfills (which we simulate using the 10-meter well distance), and (3) at a distance of 150 meters from the unit boundary. This figure reveals that the well distance distribution has a profound effect on risk. While about 5.6 percent of the landfills have risks exceeding 10^{-5} at the actual exposure points, about 34 percent exceed this risk level at the unit boundary and 20 percent do so at the 150-meter distance. Less than one-fifth of the landfills have risks higher than 10^{-6} when we consider the actual well distribution, compared to about 65 percent at both the unit boundary and the 150-meter distance.

- Water Table Depth. Figure V-29 shows a very slight difference between risk distributions in shallow and deep water table settings. The deep settings have about 3 percent fewer scenarios in the moderate- and high-risk ranges. This slight shift toward lower risk in deep water table settings results from longer unsaturated zone travel times, which allow for more pollutant degradation prior to release to the aquifer. This effect is probably more pronounced in the arid regions, where the differences in unsaturated zone travel times between the deep and shallow settings are greater.

Results of a regression analysis of the data support this conclusion. The R-squared of 0.03 in the equation linking log of risk to unsaturated zone travel time indicates that unsaturated zone travel time explains only 3 percent of the variation in risk and therefore has little impact on overall risk.

- Net Infiltration. Wetter climates are associated with higher release volumes and consequently greater risks, as shown by Figure V-30. In the 0.25" setting, risk exceeds 10^{-6} in only 15 percent of the scenarios and never exceeds 10^{-5} . In the wettest setting (20"), risk falls into the moderate (10^{-6} : 10^{-5}) range in over 30 percent of the scenarios and into the high range (greater than 10^{-5}) in over 42 percent of the scenarios. In the intervening net infiltration settings, risk increases with infiltration. The high-risk profile associated with the 20-inch infiltration region is mitigated by its relatively low frequency (about 12 percent). Over two-thirds of the landfills are split about equally between the 0.25- and 10-inch settings, which have the greatest effect on the overall risk distribution. The results of our regression analysis show a moderate relationship between net infiltration and log of risk (R-squared = 0.35). However, the fact that net infiltration is a categorical variable with

Figure V-29

DISTRIBUTION OF AVERAGE RISK - BENE

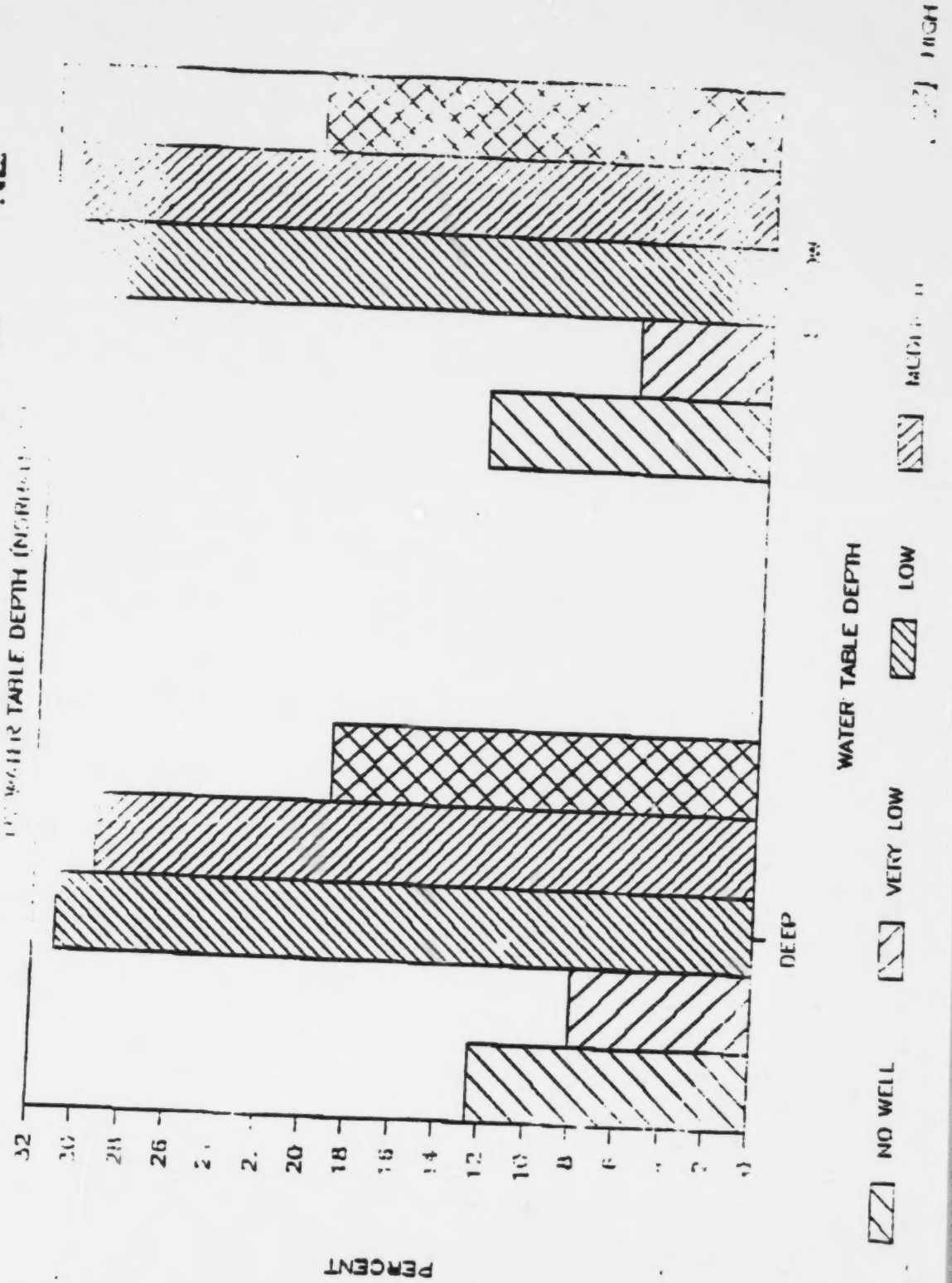
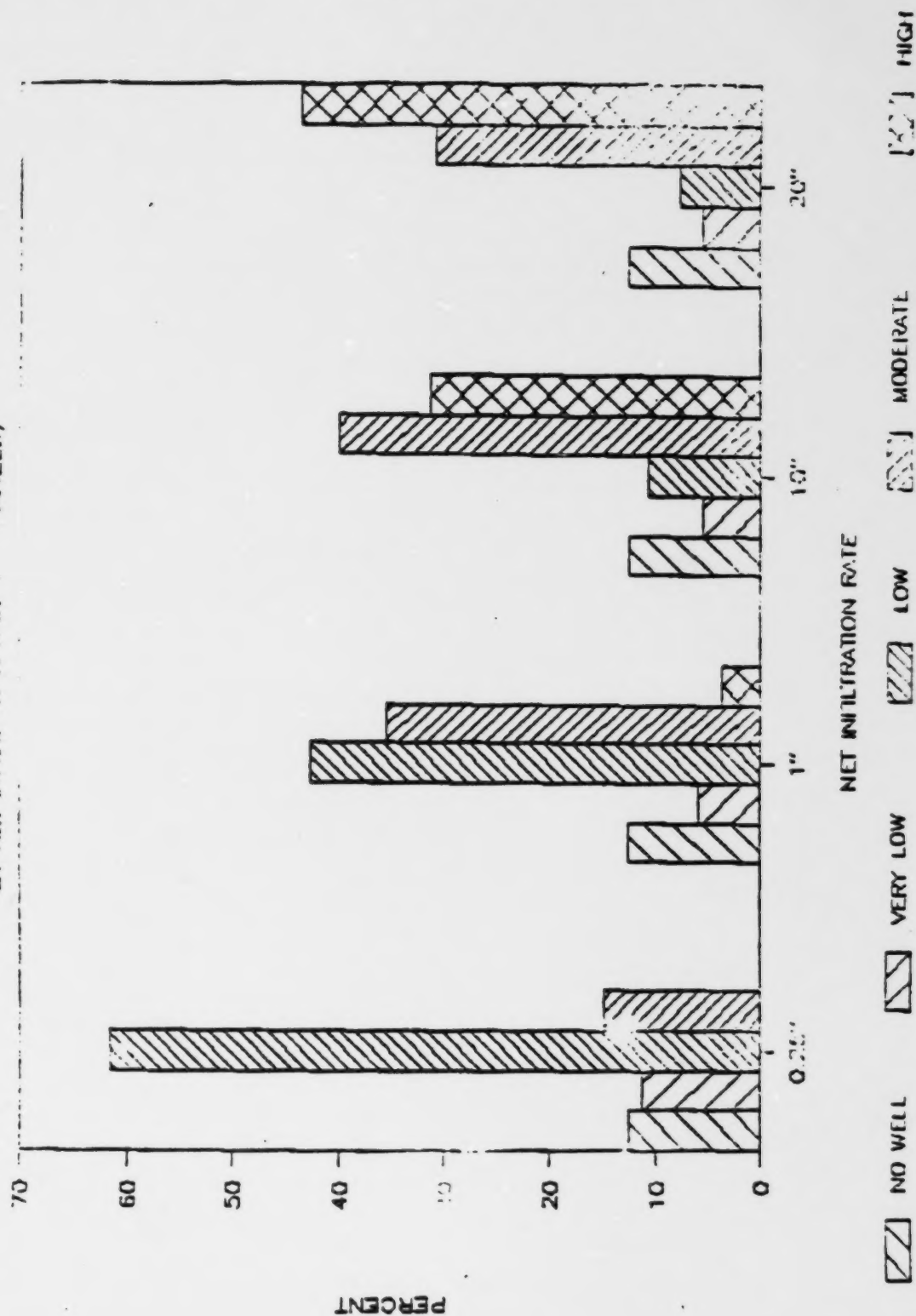


Figure V-30

DISTRIBUTION OF AVERAGE RISK -- BASELINE

BY NET INFILTRATION RATE (PERCENT)



only four values limits the usefulness of least squares regression as an analytical tool as well as the validity of the results.

- Flow Fields. Hydrogeologic characteristics of the aquifer exert a strong influence on risk. Aquifer properties affect the extent of dilution of the leachate, and the retardation and degradation of pollutants.

Of the five single-layer flow fields (i.e., water table aquifers defined by flow fields A through E) that are simulated, the slowest (flow field A, 1 m/yr velocity) and the fastest (flow fields D and E, velocities of 1,000 m/yr and 10,000 m/yr, respectively) have lower risk profiles than the intermediate velocity ones (see Figure V-31). The slow velocity of flow field A prevents pollutants from reaching the more distant wells during the modeling period, and allows for considerable pollutant degradation before breakthrough at nearby wells. In the high-velocity flow fields, the large volumes of water flowing through the aquifer afford more dilution of the leachate. Flow fields B and C (10 m/yr and 100 m/yr, respectively) have higher risk profiles because they neither allow for much degradation nor provide for much dilution or dispersion of pollutants.

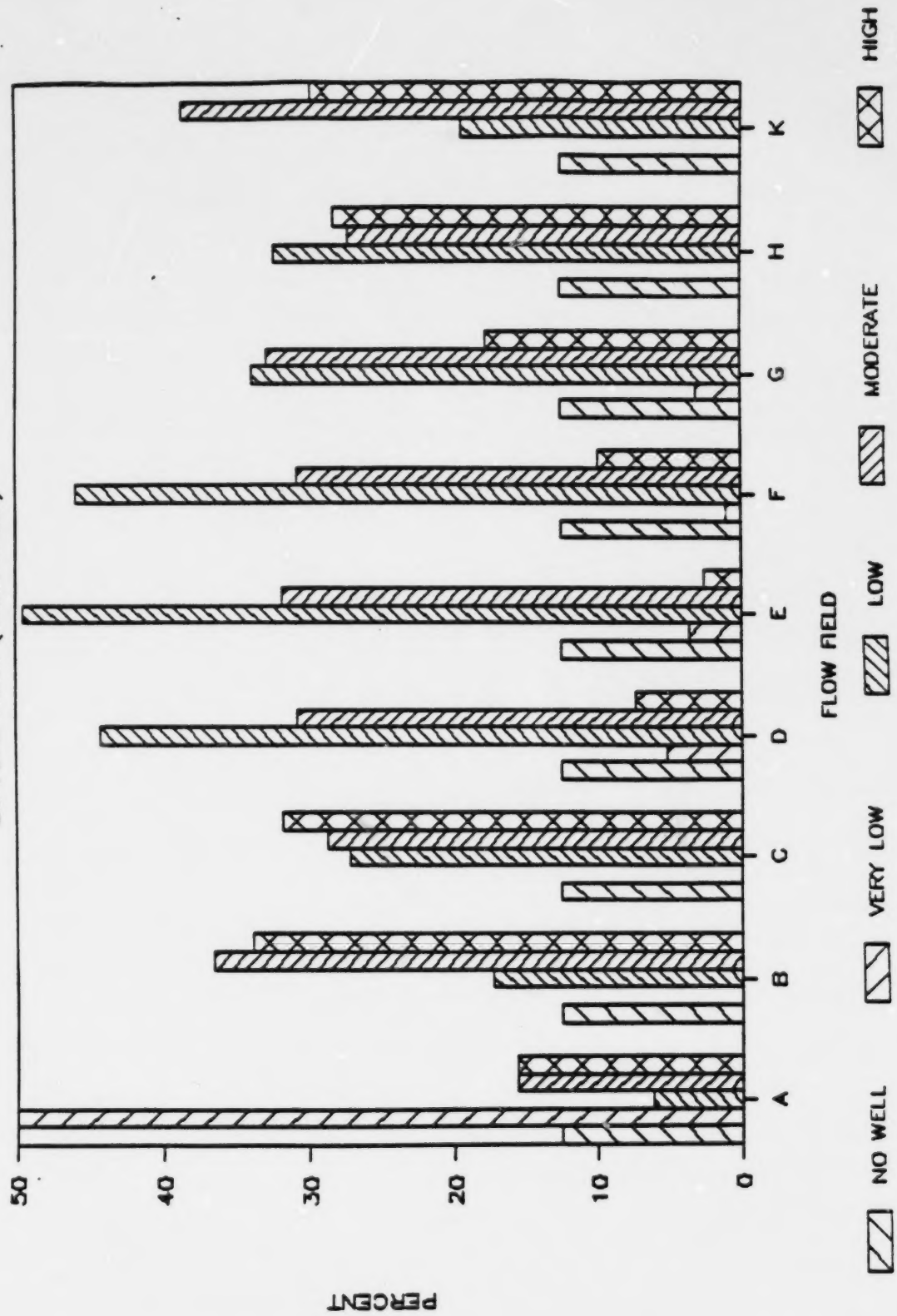
The leaky confined aquifers (flow fields F and K) have somewhat lower risks than the corresponding single-layer flow fields with similar characteristics (B and C). The risks are reduced due to the additional degradation and attenuation that occur during seepage through the confining layer.

Finally, the double-layer flow fields (G and H) have risks somewhat lower than the similar single-layer flow fields (B and C). The double-layer flow fields each have a 10 m/yr layer and a 100 m/yr layer, but differ in geometry and layer thickness. These flow fields have slightly higher rates of aquifer flux than do either flow fields B or C, and thus have slightly more dilution capacity. Also, because we estimate concentrations for the lower layers in flow fields G and H, attenuation and degradation in the upper layer act to reduce risks.

- Constituent Concentrations in Leachate. As discussed in Chapter IV, our simulation of baseline risk was based on the median levels of contaminants observed in leachate at actual landfills. This means that half of the landfills would be expected to have leachate with higher contaminant levels than what we simulated, and half would have

Figure V-31

DISTRIBUTION OF AVERAGE RISK - BASELINE BY FLOW FIELD (NORMALIZED)



lower. To place an approximate upper bound on contaminant concentrations and the associated risk levels, we determined the 90th percentile level of each constituent of concern and compared it to the median level. Table V-33 shows the ratios of the 90th percentile to the median level for each of the six constituents that we modeled for human health risk.

Table V-33	
RATIOS OF 90th PERCENTILES TO MEDIAN LEVELS FOR CONSTITUENTS OF CONCERN	
<u>Constituent</u>	<u>Ratio</u>
Carbon tetrachloride	16.3
Vinyl chloride	12.8
Dichloromethane	11.1
1,1,2,2-Tetrachloroethane	10.6
Arsenic	4.4
Antimony	2.2

The 90th percentile concentrations of the three principal constituents contributing to risk (vinyl chloride, dichloromethane, and 1,1,2,2,-tetrachloroethane) are about one order of magnitude higher than their median levels. Because all of these constituents are carcinogens, and because cancer risk varies linearly with dose, we believe that the risk associated with the 90th percentile levels would be about one order of magnitude higher than that simulated using the median levels. This indicates that at 10 percent of the landfills, risks from individual constituents could be 10 times higher than our results indicate.

Summary. About 17 percent of landfills have risks exceeding 10^{-6} , a proportion that could increase if new wells are drilled in the vicinity of landfills or if new landfills are sited near existing wells. When we consider the factors that influence risk, we find that infiltration rate, facility size, distance from the facility, and aquifer characteristics are strong determinants of risk. It is important to note, however, that no single factor is responsible for most of the variability; instead there is a complex interaction among factors. Therefore, it is difficult to reliably predict risk without accounting for the interaction among the factors we have modeled. Moreover, because our model employs a number of simplifying assumptions, there are many additional interactions not accounted for here.

Risk Reduction--Proposal

In this section we discuss the effectiveness of the Proposal in reducing risk to human health. As discussed in the methodology section, we simulated risk for each scenario using three designs: unlined with vegetative cover, unlined with synthetic cover, and synthetic-lined with synthetic cover. These three designs were used for modeling purposes only; other designs exist that would comply with the performance standard. We assigned all landfills to the least stringent design capable of meeting the design goal. We assumed that the design goal was set to require average lifetime risk at the compliance point to be 10^{-5} or less. If the most stringent design, synthetic/synthetic, did not reduce risk to this level, corrective action would be triggered. States may choose a design goal anywhere in the protective range of 10^{-4} to 10^{-7} . To the extent that states set the goal at a level other than 10^{-5} , the benefits from the rule will differ from those presented here.

The compliance point was set at the unit boundary, which we simulated using the 10-meter well distance. To simulate an alternative compliance point, we assumed that states would exercise their flexibility to set a POC 150 meters from the unit. We set the POC 150 meters from the unit and interpolated risk results from the 60-meter and 200-meter wells.²

²In the Liner Location Model, two of the ground-water flow fields (G and H) are double-layer systems in which one aquifer overlies another. In our modeling, we assume that exposure wells draw from the bottom aquifer. The dynamics of ground-water flow in these systems are such that contaminants often do not enter the bottom aquifer until they travel past the 10-meter (and sometimes the 150-meter) well, leading us to simulate relatively low risk at these distances. However, we assume that ground-water monitoring wells draw from the top aquifer, and use the concentration profiles at the 10-meter (or 150-meter) distance in the top aquifer to determine compliance with the performance standard. Because pollutant levels can be higher in the top-aquifer monitoring well than they are in the bottom-aquifer exposure well in these two flow fields, we sometimes assign more stringent designs or corrective action when risk at the exposure well is below 10^{-5} . This is the case for all of the regulatory alternatives.

We simulated 80 years of post-closure care to represent extended post-closure care. Post-closure care includes maintenance of the vegetative portion of the cover, ground-water monitoring, and corrective action. For landfills with synthetic liners or covers, we assume that the synthetic system components are maintained only during the first 30 years of post-closure care.

We present the results of our analysis below, first for the 10-meter and then for the 150-meter compliance point.

Proposal--10-Meter Point of Compliance (POC)

We estimate that for about 61 percent of all landfills, vegetative covers alone are sufficient to meet a 10^{-5} risk-based design goal if the compliance point is at the unit boundary. Synthetic covers are sufficient for 11 percent of the landfills, while synthetic liners plus LCSs and synthetic covers are needed at the remaining 28 percent. About 40 percent of the landfills with synthetic liners and covers (11 percent of all landfills) trigger corrective action under the Proposal.

Figure V-32 shows the distribution of 300-year average MEI risk for both the baseline and the Proposal (10-meter POC). About 0.1 percent of the landfills have risks exceeding 10^{-5} under the Proposal, compared to 5.6 percent in the baseline. About 35 percent of the landfills have risks between 10^{-8} and 10^{-5} under the Proposal, which is slightly higher than it is in the baseline (30 percent); this reflects a shift in risk from the high to the moderate and low risk categories. The percent of landfills with risks below 10^{-8} is about equal for both the baseline and the Proposal.

Figure V-33 shows the risk reduction achieved under the Proposal (10-meter POC) for all combinations of landfill size, environmental setting, flow field, and well distance. The points plotted in this figure do not reflect the frequency of occurrence of each combination and do not include scenarios with baseline risk below 10^{-10} . The x-axis represents the log of 300-year average MEI risk in the baseline, and the y-axis is the log of risk under the 10-meter POC Proposal. If the point lies on the equal-risk line (the solid line extending diagonally across the graph), the risk under the Proposal is equal to baseline risk (i.e., the regulation does not reduce risk). If the point lies below the equal-risk line, risk is reduced by the Proposal.

Figure V-33 shows numerous points on the equal-risk line (i.e., scenarios for which the Proposal does not reduce risk). These are associated with landfills that are already in

Figure V-32

DISTRIBUTION OF AVERAGE RISK

PROPOSED OPTION (10-METER POC) AND BASELINE

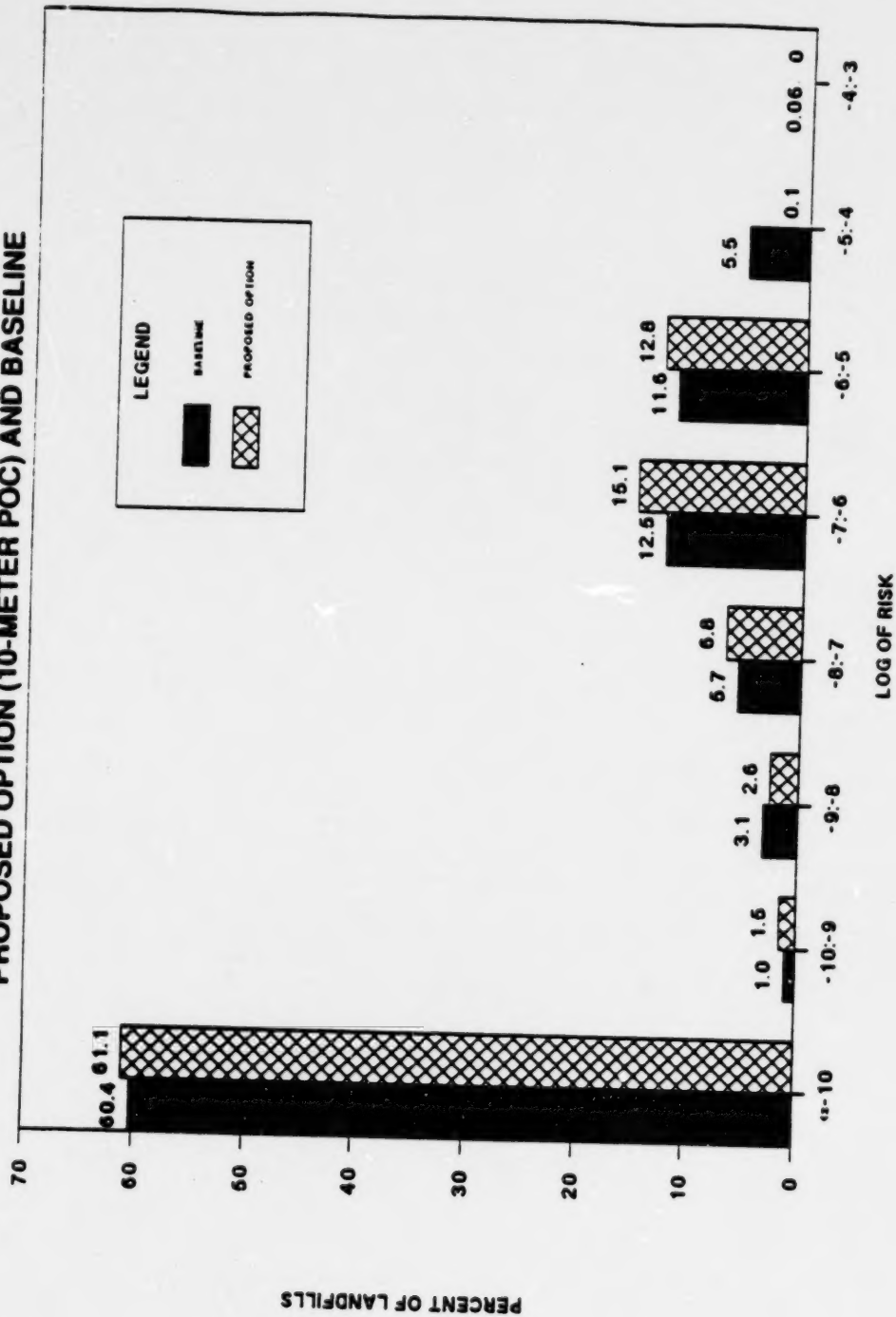
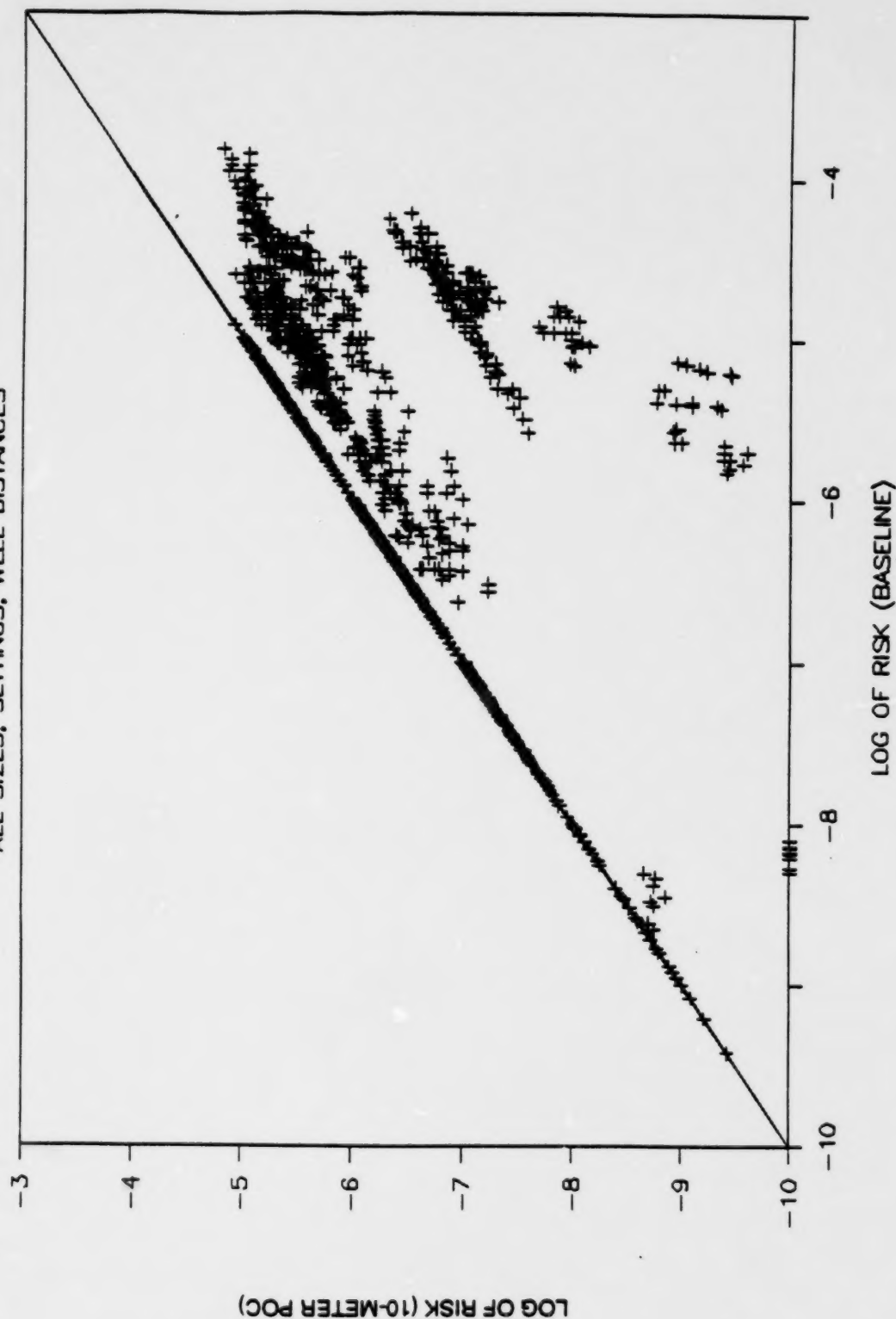


Figure V-55

BASELINE VS. PROPOSAL-10-METER POC AVG. RISK

ALL SIZES, SETTINGS, WELL DISTANCES



compliance with the performance standard in the baseline. All scenarios with baseline risks higher than 10^{-5} show some risk reduction under the Proposal; for these scenarios, risk is usually reduced by less than an order of magnitude, but is virtually always reduced to less than 10^{-5} . Scenarios that have more than an order-of-magnitude risk reduction are associated with landfills that trigger corrective action (about 11 percent of all landfills). Figure V-33 also shows variable amounts of risk reduction for several scenarios with baseline risk below 10^{-5} . Some of these points represent exposure distances of 60 meters or more at landfills that must implement more stringent containment to meet the performance standard at the unit boundary. Others correspond to landfills in flow fields G and H, which are assigned more stringent designs or corrective action based on pollutant levels in the monitoring wells rather than the exposure wells.

Population risks are 0.0210 cancer cases per year (over the 300-year modeling period), down from a baseline of 0.0770 cases per year.

Proposal--150-Meter POC

The alternative compliance point for the performance standard is 150 meters from the waste boundary. We estimate that 79.1 percent of the landfills are in compliance with a 10^{-5} design goal in the baseline. About 8.5 percent need synthetic covers, and the remaining 12.4 percent need synthetic liners and synthetic covers. About 40 percent of the landfills with the synthetic/synthetic design, or 5 percent of all landfills, trigger corrective action.

Figure V-34 shows the distribution of 300-year average MEI risk for both the baseline and the Proposal (150-meter compliance point). As with the 10-meter POC, the number of landfills with risks exceeding 10^{-5} is reduced from 5.6 percent in the baseline to about 0.1 percent. The percentage with risks between 10^{-6} and 10^{-5} is 14.1, compared with 12.8 percent using the 10-meter POC and 11.6 percent in the baseline. About 86 percent of the landfills have risks lower than 10^{-6} under this option, compared to 83 percent in the baseline.

Figure V-35 shows the risk reduction achieved under the Proposal for all combinations of landfill size, environmental setting, flow field, and well distance. The points plotted in this figure do not reflect the frequency of occurrence of each combination and do not include scenarios with baseline risk

Figure V-34
DISTRIBUTION OF AVERAGE RISK
PROPOSED OPTION (150-METER POC) AND BASELINE

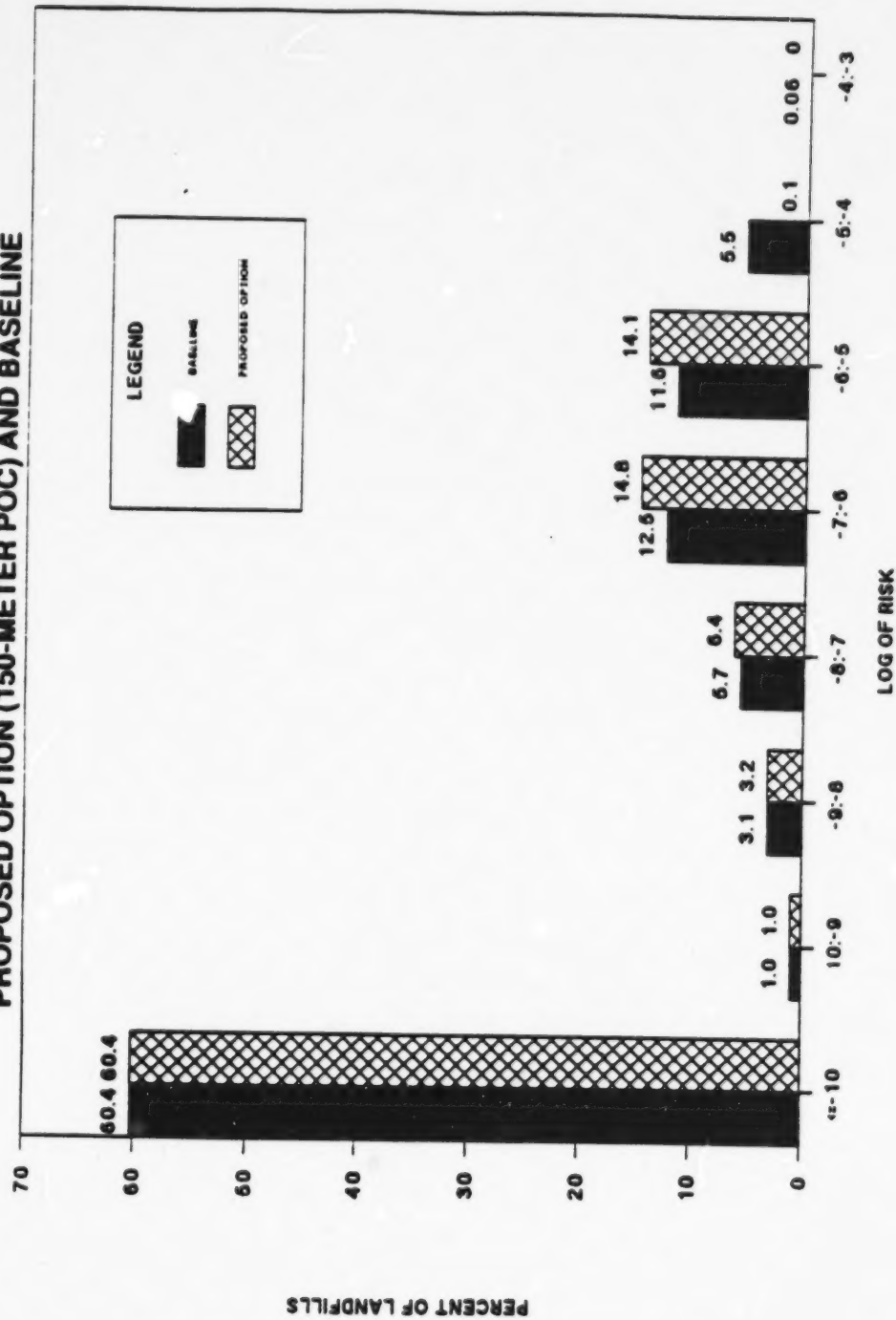
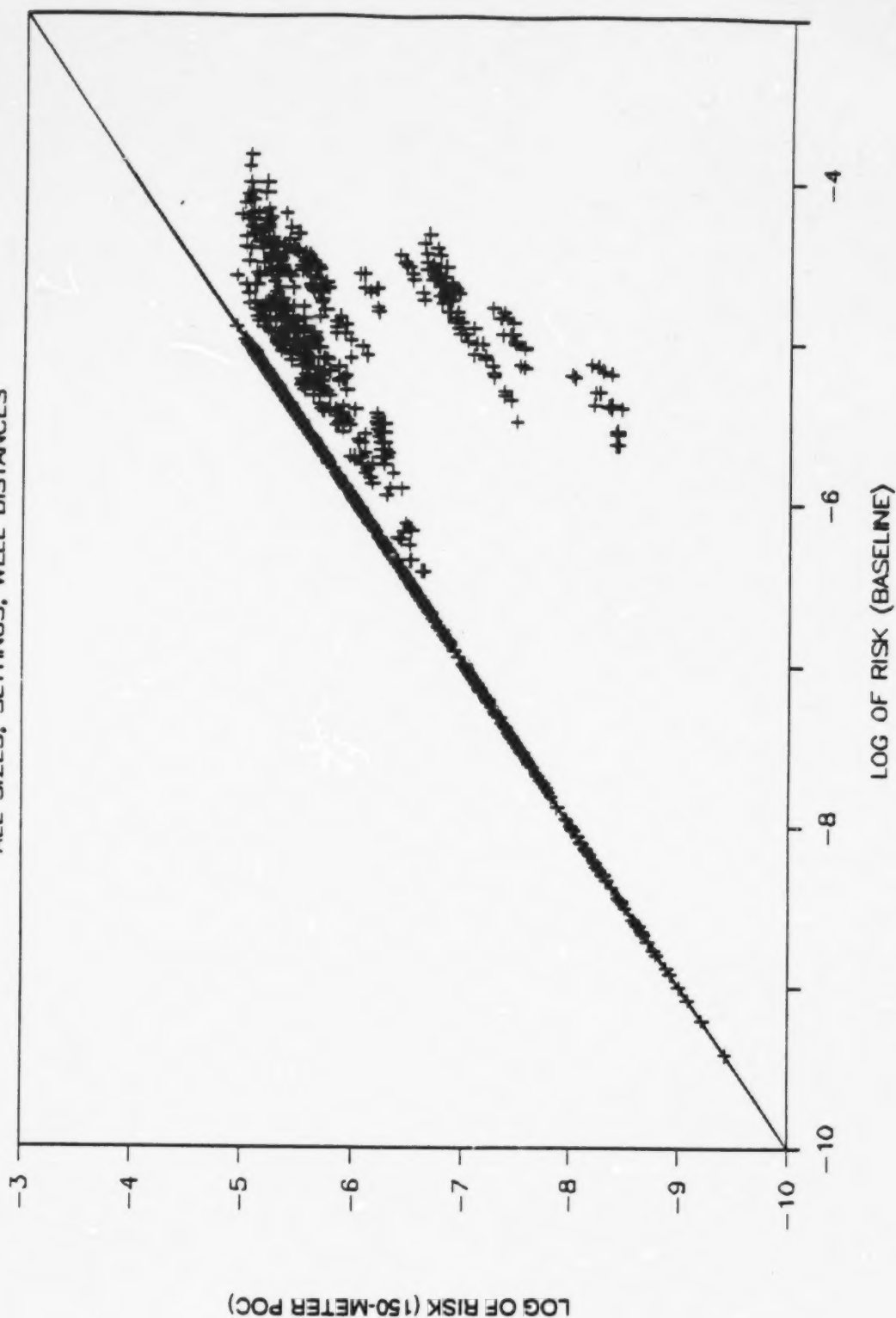


Figure V-55

BASELINE VS. PROP.-150-METER POC AVG. RISK

ALL SIZES, SETTINGS, WELL DISTANCES



below 10^{-10} . We have also excluded scenarios with well distances of 10 or 60 meters, and replaced them with scenarios that correspond to the 150-meter well distance. Compared to the 10-meter POC, fewer scenarios show risk reduction using the 150-meter POC; this is because only 21 percent of the landfills need more stringent containment to meet the performance standard at the 150-meter compliance point, compared to 39 percent at the 10-meter compliance point. For scenarios with the unlined/synthetic or synthetic/synthetic design, the magnitude of the risk reduction is comparable to that observed for the Proposal with a 10-meter POC.

Population risks are 0.0227 cancer cases per year (over the 300-year modeling period), down from a baseline of 0.0770 cases per year.

Risk Reduction--Alternative 1

Of all the regulatory options being considered, Alternative 1 has the most stringent containment, leachate collection, and cover requirements: a synthetic/composite liner (two synthetic membranes overlying three feet of clay), two leachate collection systems, and a composite cover (synthetic membrane overlying clay). These requirements are imposed uniformly on new landfills.

As with the Proposal, we simulated 80 years of post-closure care to represent extended post-closure care. Post-closure care includes maintenance of the vegetative portion of the cover, ground-water monitoring, and corrective action. We assume that the synthetic components are maintained only during the first 30 years of post-closure care. Corrective action is triggered if the containment systems do not reduce 300-year average most exposed individual risk to 10^{-5} at the unit boundary.

Figure V-36 shows the distribution of 300-year average MEI risk for both the baseline and Alternative 1. About 0.03 percent of the landfills have risk greater than 10^{-5} at exposure wells under Alternative 1, compared to 5.6 percent in the baseline; about 6.1 percent have moderate risk (10^{-6} to 10^{-5}) compared to 11.6 percent in the baseline; 15.2 percent have low risk (10^{-8} to 10^{-6}); and the remaining 78.7 percent have very low or no risk.

Figure V-37 shows the risk reduction achieved under Alternative 1 for all combinations of landfill size, environmental setting, flow field, and well distance. The points plotted in this figure do not reflect the frequency of occurrence of each combination and do not include scenarios with baseline risk below 10^{-10} . The figure shows that in most cases risk is

Figure V-36
**DISTRIBUTION OF AVERAGE RISK
 ALTERNATIVE 1 AND BASELINE**

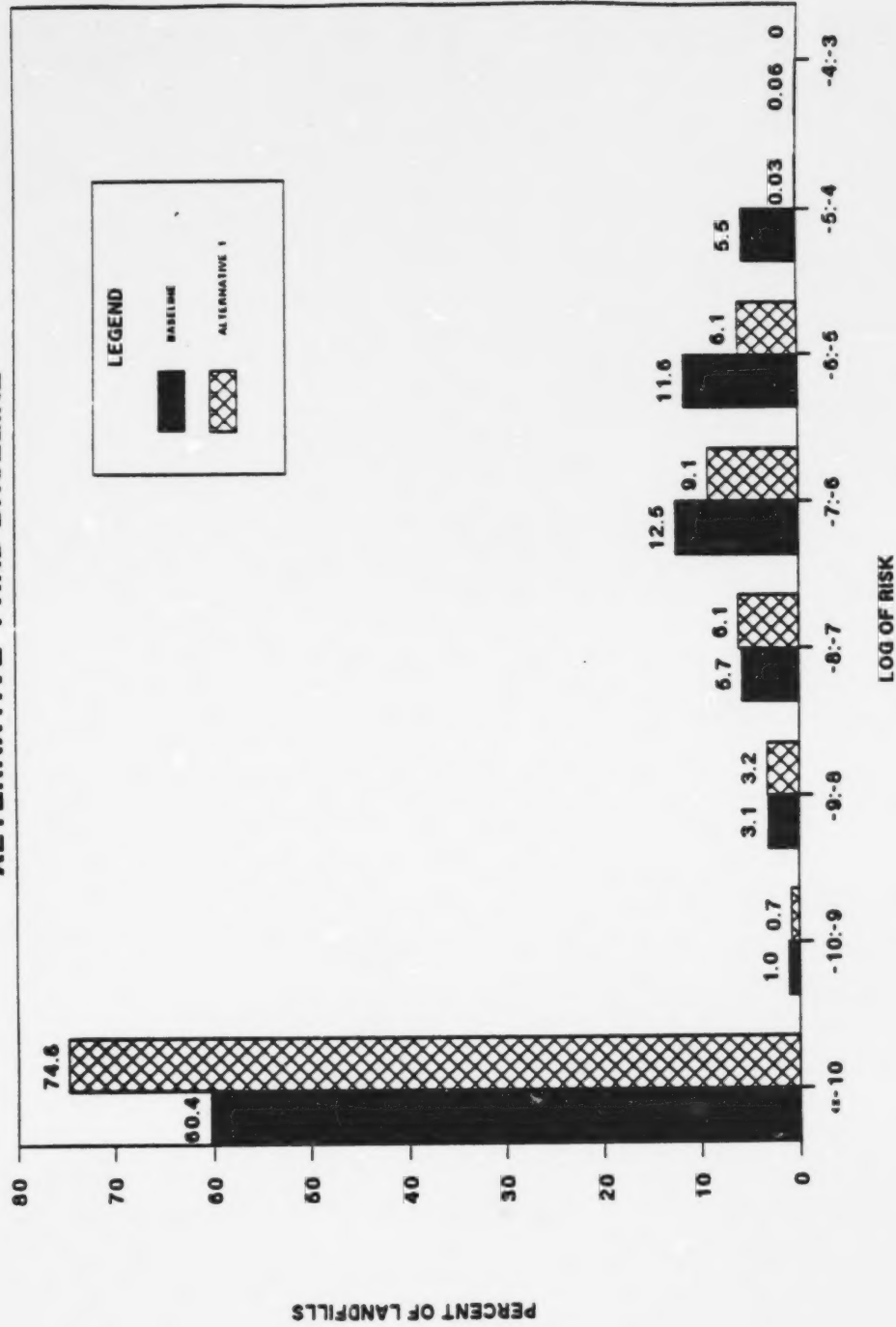
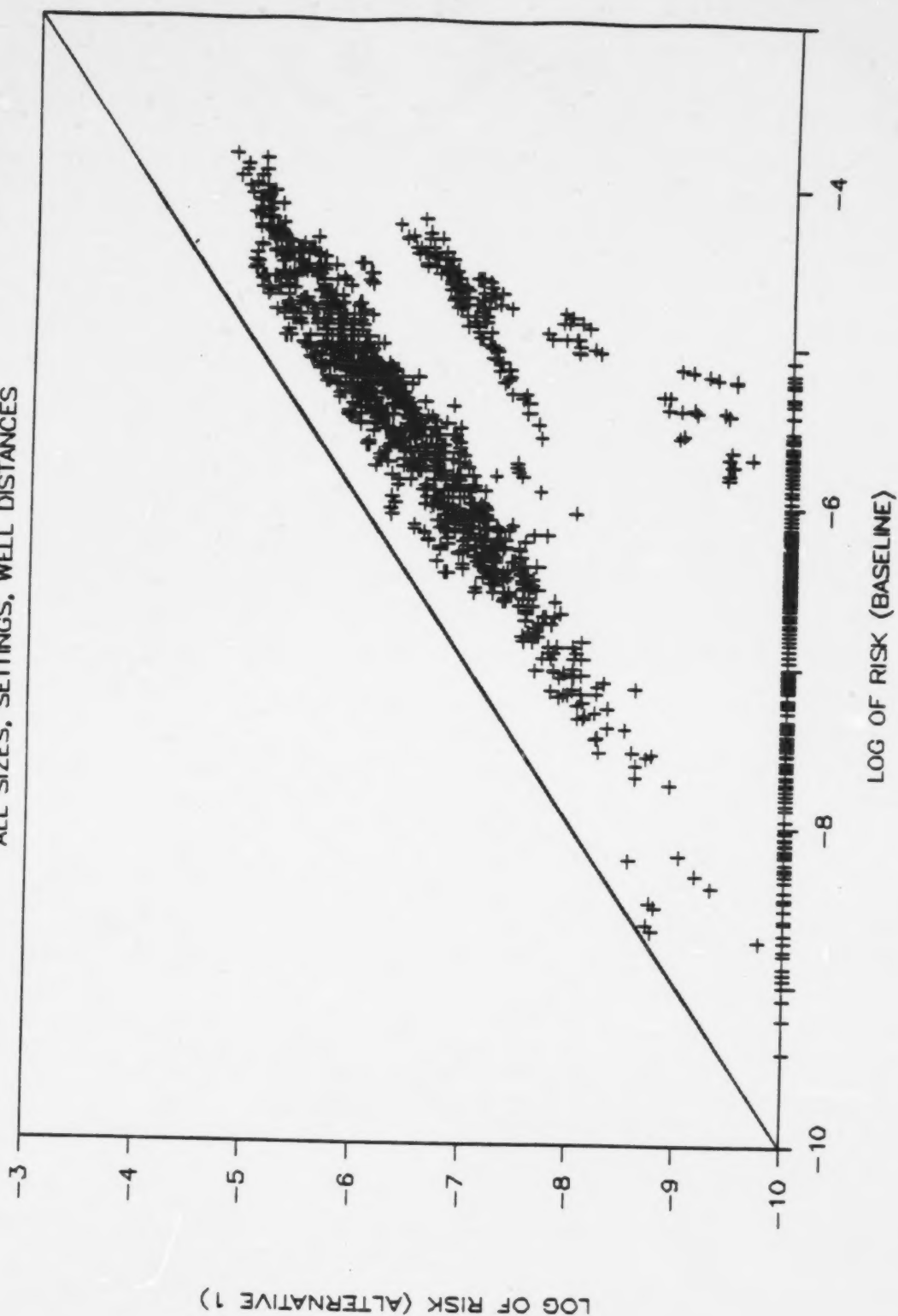


Figure V-37

BASELINE VS. ALTERNATIVE 1 AVERAGE RISK

ALL SIZES, SETTINGS, WELL DISTANCES



reduced by a factor of 2 to 20 under Alternative 1. There are, however, several combinations for which the risk reduction is substantially greater.

The synthetic/composite liner, double leachate collection system, and composite cover reduce risk for several reasons. The cover reduces the amount of infiltration entering the landfill. Before leachate is released from the landfill, both synthetic membranes in the bottom liner must fail, which results in a lower LCS efficiency, and the leachate that is not collected must then travel through three feet of clay. As a result, releases are typically delayed for about 52 years in the 10-inch and 20-inch annual net infiltration regions, 74 years in the 1-inch region, and over 100 years in the 0.25-inch region. Because of this delay, some of the pollutant mass which would otherwise have been released is not released during the modeling period. The delay also results in additional pollutant degradation before release. Finally, the leachate collection systems remove some of the pollutant mass from the landfill.

This very stringent design does not reduce risk by a factor of more than about 20 in most scenarios. Most of the scenarios for which risk is eliminated are in the 0.25-inch net infiltration region, where the delay in release exceeds 100 years. Because we simulate risk resulting from only the first 100 years of release, these landfills have zero risk in our modeling. If we were to extend our pollutant release period, we would simulate positive (but small) risks for these landfills. For the cluster of scenarios with risk reductions of about two orders of magnitude or more, corrective action is responsible for the higher effectiveness. About 9 percent of the landfills trigger corrective action under Alternative 1.

Population risks are 0.0086 cancer cases per year (over the 300-year modeling period), down from a baseline of 0.0770 cases per year.

Risk Reduction--Alternative 2

Under Alternative 2, landfills that are located in areas with greater than 40 inches of annual precipitation or that generate more than one foot of leachate during their active life are required to have leachate collection systems. All landfills must meet performance standards relating to time of travel to the uppermost aquifer and to infiltration of water through the cover. Landfill owner/operators can use a number of different liner/cover configurations, provided that they demonstrate the performance standards will be met.

To analyze the effectiveness of Alternative 2, we made some simplifying assumptions to assign each size/environmental setting/flow field scenario to one of four designs: unlined with vegetative cover, clay-lined with vegetative cover, unlined with synthetic cover, and synthetic-lined with synthetic cover. We assumed that synthetic components would be maintained for the first 30 years of post-closure care, and that maintenance of the vegetative portion of the cover, ground-water monitoring, and corrective action (if necessary) would be conducted for an additional 50 years. The point of compliance for corrective action is the unit boundary.

Figure V-38 shows the distribution of 300-year average most exposed individual risk for both the baseline and Alternative 2. The figure shows a shift in risk from the moderate and high risk ranges to the low and very low categories. Only 0.03 percent of the landfills have risks exceeding 10^{-5} under Alternative 2, compared to 5.6 percent in the baseline, and 7.9 percent have risks between 10^{-6} and 10^{-5} , compared to 11.6 percent in the baseline. The percent of landfills with risks below 10^{-6} increases from about 83 percent in the baseline to about 92 percent under Alternative 2.

Figure V-39 shows the risk reduction achieved under Alternative 2 for all combinations of landfill size, environmental setting, flow field, and well distance. The points plotted in this figure do not reflect the frequency of occurrence of each combination and do not include scenarios with baseline risk below 10^{-10} . As with the Proposal, risk remains unchanged from the baseline for many scenarios; points on the equal-risk line correspond to landfills which need only vegetative covers to comply with Alternative 2 design and performance standards. Unlike the Proposal, the performance standards under Alternative 2 are not strictly risk-based, resulting in the need for liners and/or covers at some landfills with low baseline risk. We therefore see some risk reduction even at the low ends of the baseline risk range. Risk is generally reduced by a factor of 0 to 10 under Alternative 2, but the reduction is greater in some cases. About 11 percent of all landfills trigger corrective action under Alternative 2.

The expected number of cancer cases under Alternative 2 is 0.0105 per year (over the 300-year modeling period), compared to 0.0770 in the baseline.

Risk Reduction--Alternative 3

Alternative 3 requires extended ground-water monitoring and corrective action, but imposes no design standards. To analyze

Figure V-38

DISTRIBUTION OF AVERAGE RISK ALTERNATIVE 2 AND BASELINE

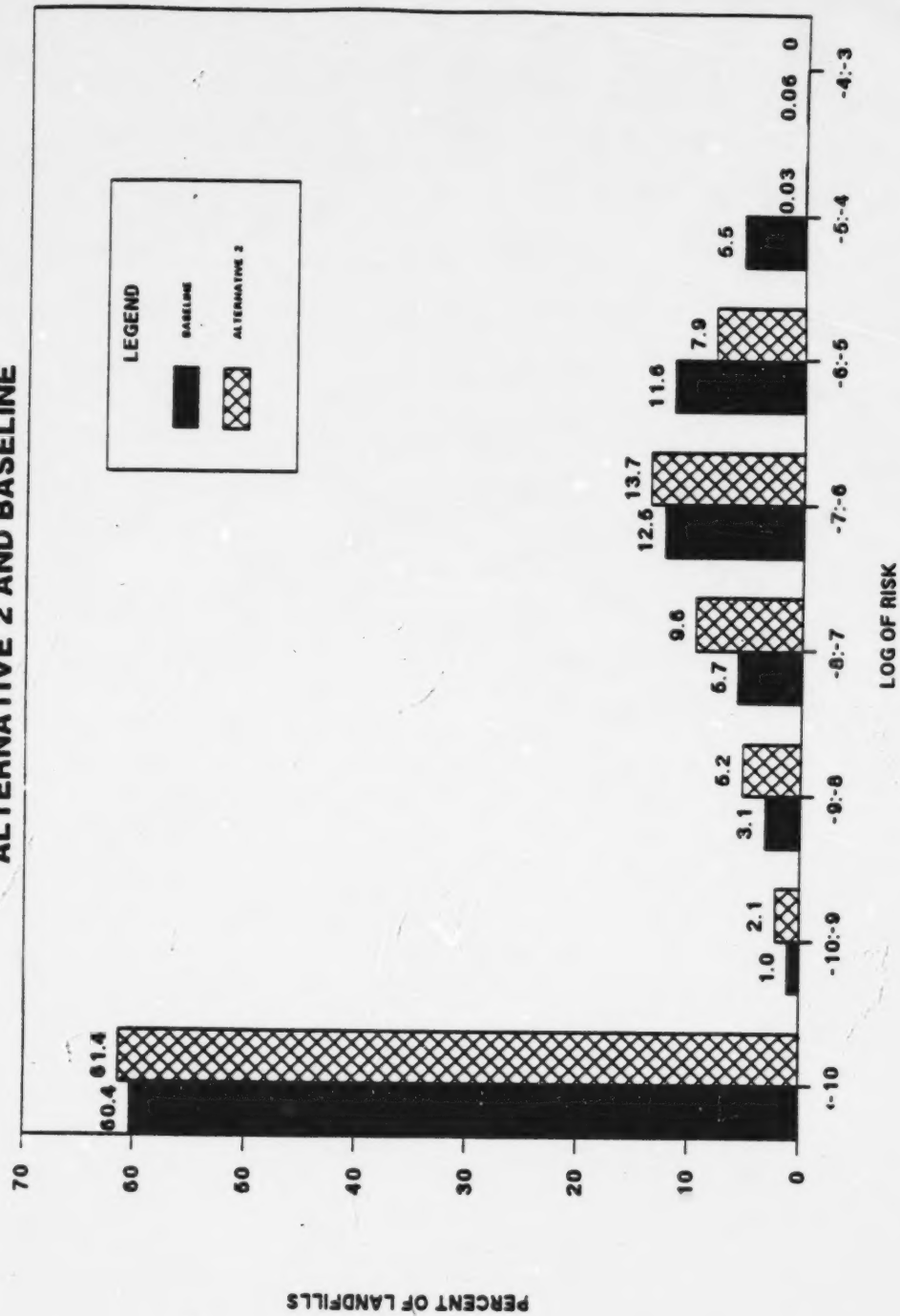
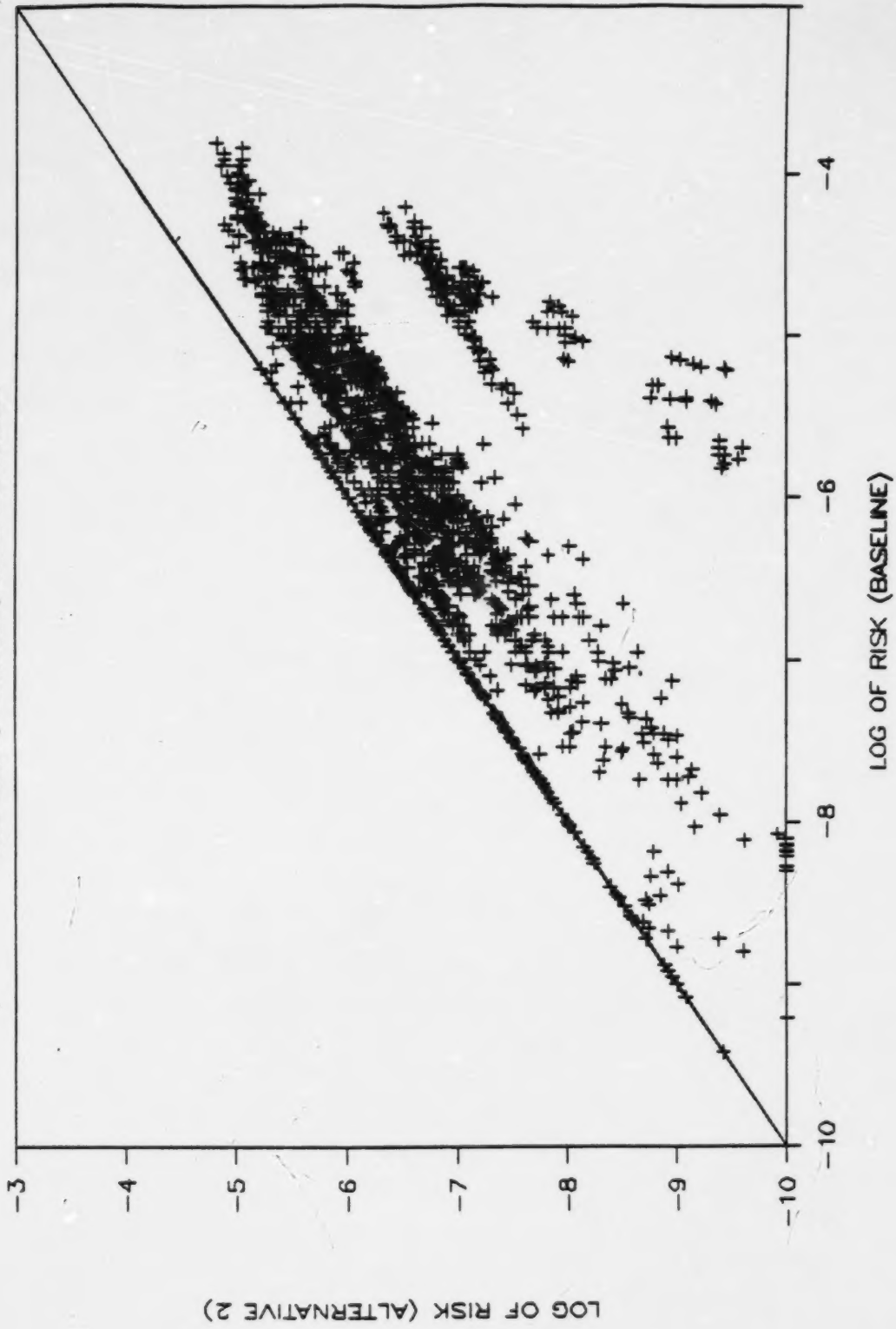


Figure V-39

BASELINE VS. ALTERNATIVE 2 AVERAGE RISK

ALL SIZES, SETTINGS, WELL DISTANCES



the effectiveness of this Alternative, we assumed that corrective action would be triggered at all landfills with 300-year average MEI risk greater than 10^{-5} at the unit boundary. As with the other alternatives, the only corrective action technology that we simulate is ground-water recovery wells. We estimate that 39 percent of the landfills will trigger corrective action under this alternative.

Figure V-40 shows the distribution of 300-year average most exposed individual risk for both the baseline and Alternative 3. Under Alternative 3, 0.003 percent of landfills have risks higher than 10^{-4} , compared to 0.06 in the baseline. The percent of landfills with risks between 10^{-5} and 10^{-4} decreases from 5.5 to 1.8 percent under this alternative, and the percent with risks between 10^{-6} and 10^{-5} decreases from 11.6 to 8.7 percent. About 11 percent of the landfills have risks higher than 10^{-6} under Alternative 3, compared to 17 percent in the baseline.

Figure V-41 shows the risk reduction achieved under Alternative 3 for all combinations of landfill size, environmental setting, flow field, and well distance. The points plotted in this figure do not reflect the frequency of occurrence of each combination and do not include scenarios with baseline risk below 10^{-10} . As with the Proposal and Alternative 2, risk remains unchanged for many scenarios; the points on the equal-risk line correspond to landfills that do not trigger corrective action (61 percent of all landfills). Figure V-38 shows some risk reduction for all scenarios with baseline risks exceeding 10^{-5} , the corrective action trigger level. The magnitude of the risk reduction is highly variable, because the effectiveness of ground-water recovery wells varies significantly among flow fields and among well distances within a given flow field. Figure V-41 also shows variable amounts of risk reduction for several scenarios with baseline risk below 10^{-5} . Some of these points represent exposure distances of 60 meters or more at landfills that trigger corrective action because of high risk at the unit boundary, and others are associated with flow fields G and H.

Population risks under Alternative 3 are 0.0216 cancer cases per year (over the 300-year modeling period), down from a baseline of 0.0770 cases per year.

Risk Reduction--Summary

In this section, we compare the effectiveness of the Proposal and alternatives in reducing risk to the maximum exposed individual (MEI) and to populations. As in the preceding sections, MEI risk refers to the maximum exposed individual lifetime

Figure V-40

DISTRIBUTION OF AVERAGE RISK ALTERNATIVE 3 AND BASELINE

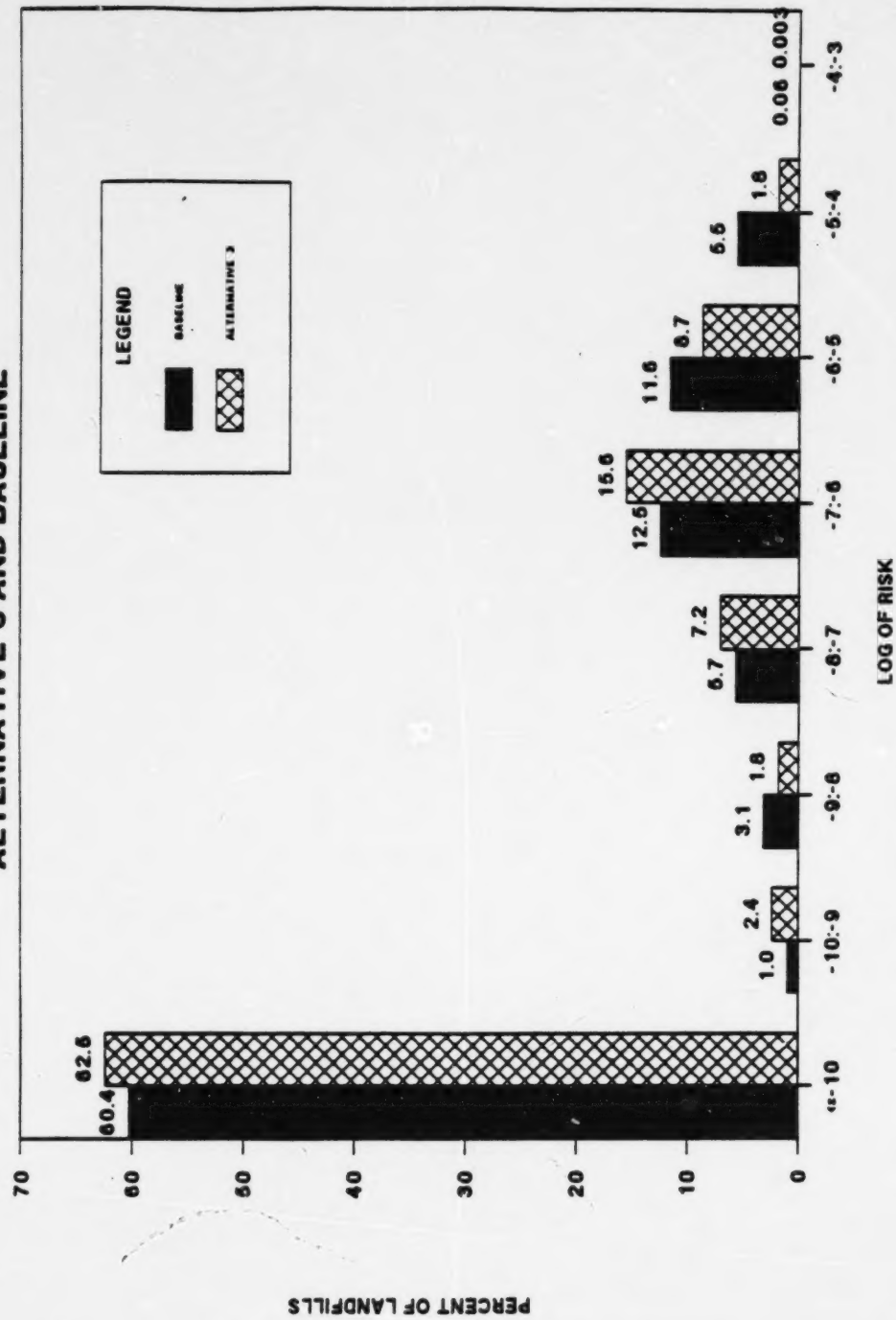
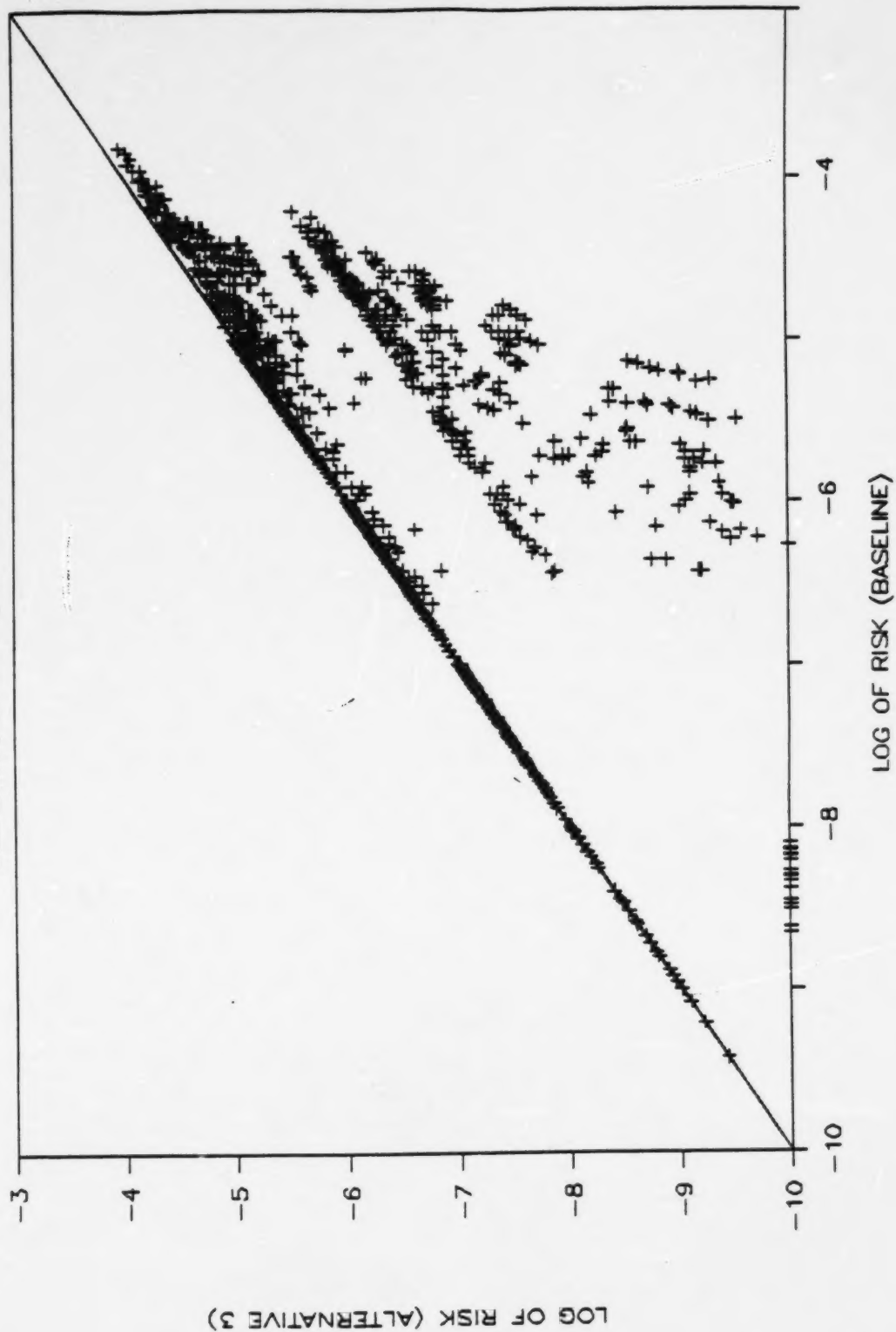


Figure V-41

BASELINE VS. ALTERNATIVE 3 AVERAGE RISK

ALL SIZES, SETTINGS, WELL DISTANCES



risk averaged over the 300-year modeling period, and population risk is expressed as the number of cases expected annually over the modeling period.

Figure V-42 shows the cumulative frequency of average individual risk for the baseline, the Proposal, and each alternative. The y-coordinate for any point on the graph corresponds to the percentage of landfills with risks exceeding the point's x-coordinate. We have excluded risks lower than 10^{-8} from the graph to provide greater resolution in the higher risk ranges.

The Proposal and Alternatives 1 and 2 all reduce the occurrence of risks higher than 10^{-5} from 5.6 percent of landfills in the baseline to one-tenth of a percent or less. Under Alternative 3, about 1.8 percent of the landfills continue to have high risks. Alternative 3 is the only regulatory option that does not impose design or performance standards, relying only on corrective action. Although corrective action is always triggered at landfills with risks exceeding 10^{-5} at the unit boundary, the recovery wells do not always reduce risks below 10^{-5} . Moreover, the uncertainty of corrective action timing, efficiency, and cost may not be well reflected in these estimates.

Table V-34 shows the estimated number of cases expected annually over the 300-year modeling period, and the reduction in annual population risk for each option. Alternative 1 is the most effective of the options, reducing the number of cases by about 89 percent. Alternative 2 is almost as effective, reducing population risks by about 86 percent. The 10-meter POC Proposal, the 150-meter POC, and Alternative 3 are virtually indistinguishable in reducing population risks; reductions range between 68 and 73 percent. Among these three options, the Proposal with a 10-meter POC is the most effective, followed by Alternative 3 and then the Proposal with a 150-meter POC.

Alternatives 1 and 2 are more effective than the Proposal and Alternative 3 in reducing population risks because the latter two only target the high-risk landfills (i.e., those with MEI risks at the compliance point of 10^{-5} or higher). Alternatives 1 and 2, on the other hand, impose more stringent containment systems on all or most of the landfills. Nevertheless, all of the options are effective in reducing the occurrence of MEI risks greater than 10^{-5} .

Figure V-42

CUMULATIVE FREQUENCY OF AVERAGE RISK

BASELINE, PROPOSAL, AND ALTERNATIVES

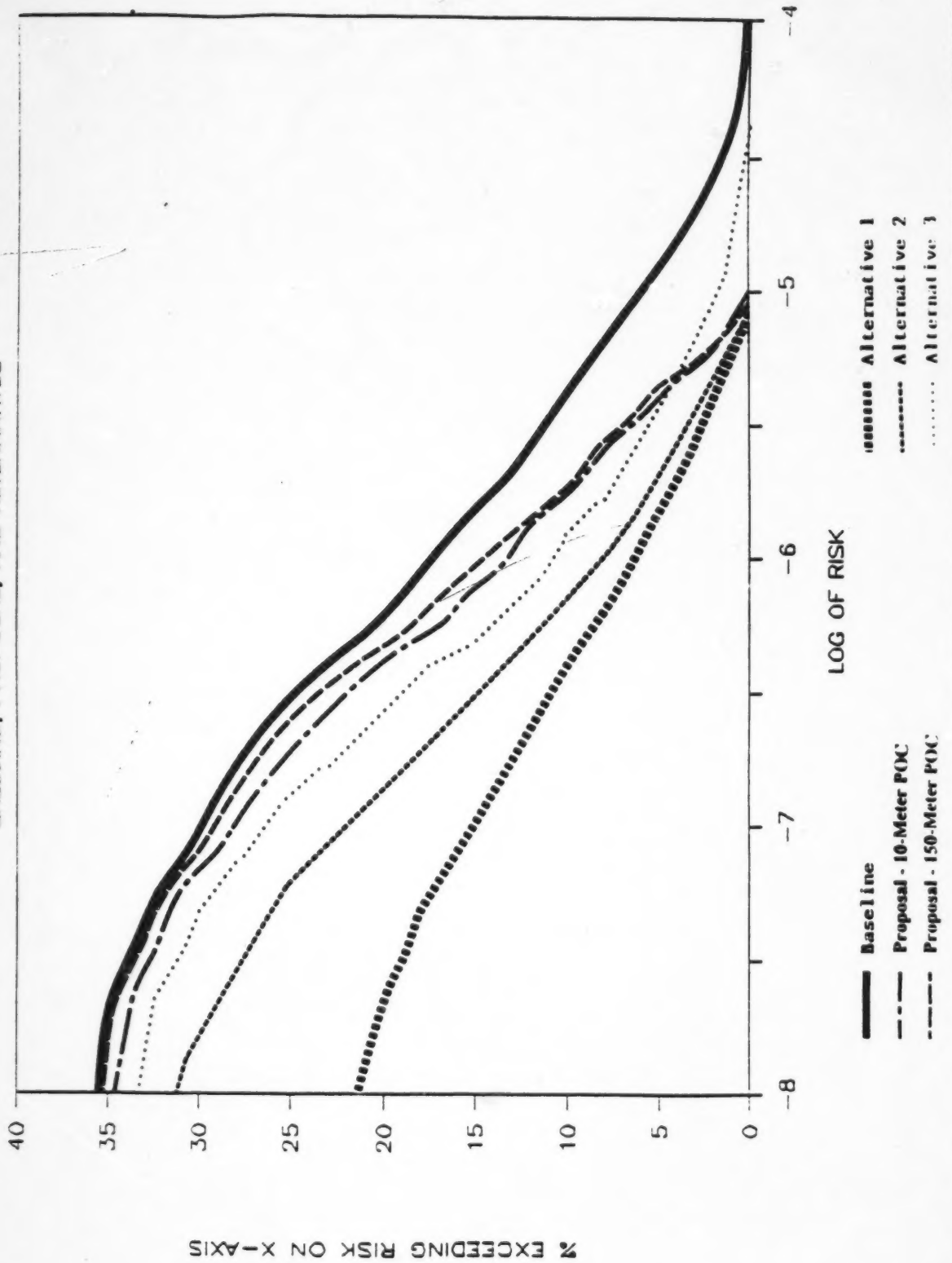


Table V-34		
PREDICTED POPULATION RISK ACROSS 6,034 NEW FACILITIES		
Regulatory Scenario	Cases per Year ¹	Reduction Cases per Year (percent)
Baseline	0.0770	-
Proposal (10-Meter POC)	0.0210	0.0560 (72.7%)
Proposal (150-Meter POC)	0.0227	0.0543 (70.5)
Alternative 1	0.0086	0.0684 (88.8)
Alternative 2	0.0105	0.0665 (86.4)
Alternative 3	0.0216	0.0554 (71.9)

¹Total population risk over the 300-year simulation period divided by 300.

Resource Damage

In this section we present the results of the resource damage analysis for the baseline, the Proposal, and each alternative. As discussed in the methodology section of Chapter IV, resource damage is measured as the cost to provide water to users whose supply is contaminated by releases from landfills. For this analysis, resource damage (i.e., replacement cost) is expressed in present-value terms.

The Subtitle D Risk Model evaluates damage in two ways. First, it calculates use value (i.e., the replacement costs for ground water currently used as a drinking water supply). Use value applies to all landfills reported to have ground-water wells within 1,600 meters. Second, it computes option value, the value of ground water that does not currently serve as a source of drinking water but that may be used in the future. Option value takes use value and multiplies it by the probability that, in a given future year, the aquifer will be used as a drinking water source. Because the probability is very low initially, and increases with time, option value is always lower than use value.

Option value applies to landfills that currently do not have any downgradient wells within one mile as reported in the MSWLF survey.

Another important point concerning resource damage results is the impact of time and discounting. In our analysis of risk, a given value is the same whether it occurs in the first year of the simulation or the last year. When considering the value of a resource, though, we discount future events using discounted cash flow analysis. Two resource damage estimates, each occurring at a different time, may have the same undiscounted value. When discounted, however, the damage that occurs later will be worth less in present value terms. As a result of this discounting, the timing of plume formation has a significant impact on the resource damage results.

Baseline Resource Damage

Our discussion of baseline resource damage parallels the discussion of baseline risk. We first examine the overall weighted distribution of resource damage, and then discuss the factors affecting baseline resource damage.

Distribution of Resource Damage. Figure V-43 presents the distribution of resource damage for all units, expressed in present value terms. The numbers on the x-axis represent the upper bound of the resource damage interval (i.e., the bar labeled 0.4 includes landfills with replacement costs that are higher than \$0.2 million but less than or equal to \$0.4 million). These results have been weighted by all the relevant factors (e.g., facility size, infiltration rates). It shows that resource damage ranges from \$0 to more than \$4 million. The majority of landfills, though, have resource damages valued at less than \$200,000. The model predicts that about 71 percent of landfills have resource damage. Only 31 percent of landfills have resource damage exceeding \$200,000, and about 13 percent have resource damage in excess of \$1 million. The figure also shows how the distribution of resource damage divides into use value and option value. Because option value is based on the probability that a ground-water source may someday be used, it tends to be much lower than use value for a given set of conditions. In fact, the model data indicate that option value is, on average, only a tenth of use value. The result is that option value dominates at lower levels of resource damage while use value is the only measure to appear at levels exceeding \$400,000.

Figure V-43
DISTRIBUTION OF RESOURCE DAMAGE
BASELINE

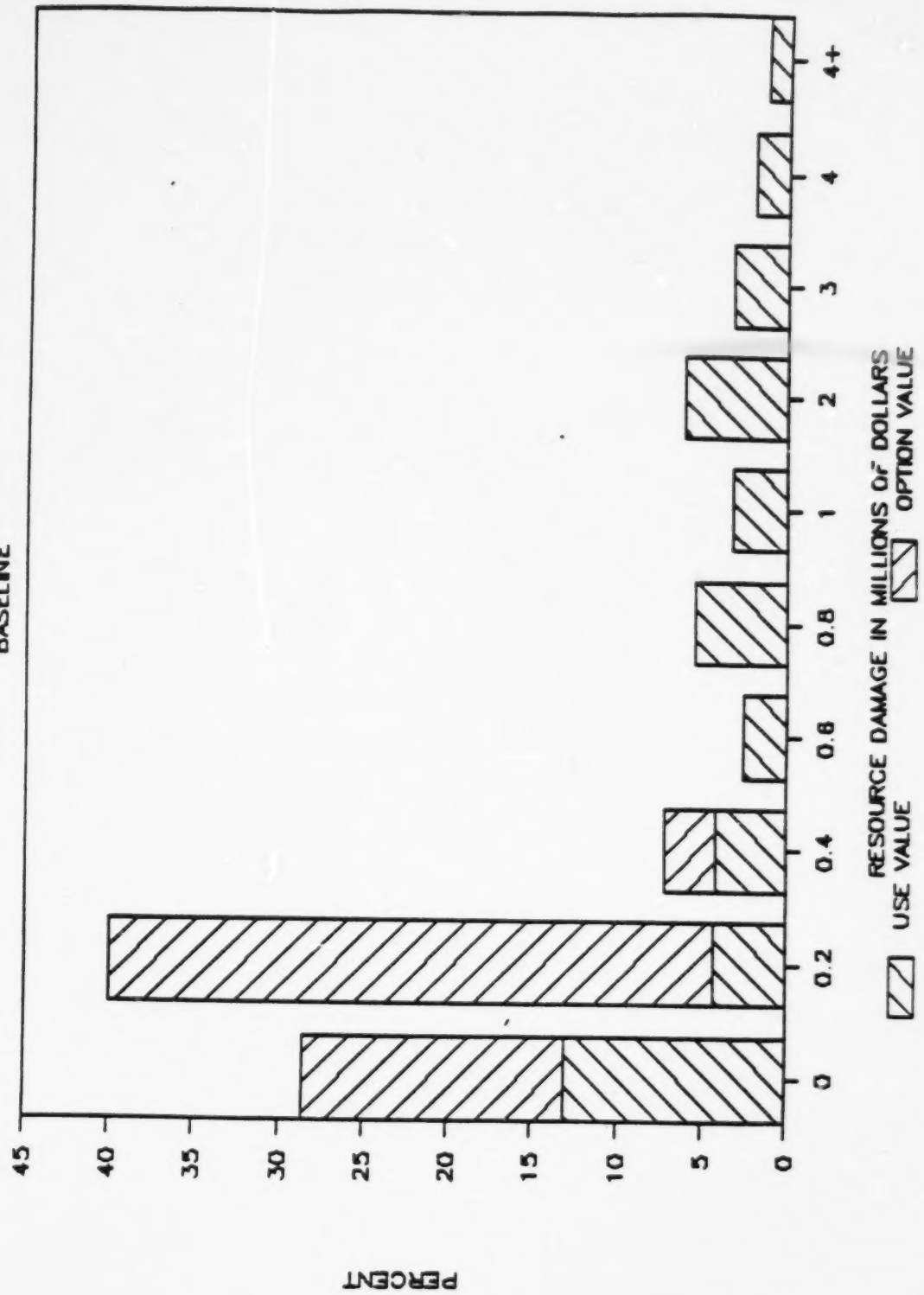


Figure V-44 summarizes the resource damage estimates in terms of a cumulative frequency distribution. This graph includes both use and option value. The median resource damage is about \$79,000; thirteen percent of the landfills have damages exceeding \$1 million, and seven percent exceed \$2 million.

Figure V-45 presents the cumulative frequency distribution for use value alone. The median replacement cost for this subset of landfills is about \$485,000, and about 28 percent of these landfills have damages that exceed \$1 million.

The total resource damage for both use and option value for 6,034 new landfills is about \$2.58 billion.

Factors Affecting Resource Damage. The Subtitle D model estimates resource damage for landfills of different sizes in a variety of environmental and hydrogeological settings. Because resource damage is affected primarily by plume size and timing we will assess the impact of size and environmental setting in terms of these two parameters. A preliminary analysis of use value and option value indicated that the two are highly correlated (Pearson's $r = .73$). Consequently, we decided that analysis of only use value would be sufficient to illustrate how resource damage varies among specific environmental factors. Thus, the percentages refer only to landfills that have wells within 1,600 meters.

- Facility Size. Figure V-46 shows that landfill size has a large impact on resource damage. Less than 30 percent of the 10-TPD scenarios have resource damage greater than \$1 million. The plurality of scenarios with small landfills have no resource damage. In sharp contrast, 66 percent of the 750-TPD scenarios have resource damage greater than \$1 million and nearly 30 percent of the scenarios have damage in excess of \$3 million. Less than 20 percent have no resource damage. The greater mass of waste and larger area of the large facilities leads to larger plumes and, as a direct result, higher resource damage. The high resource damage profile of the large landfills is mitigated by their small proportion of the landfill population.
- Water Table Depth. Water table has only a small impact upon resource damage. The slight differences in the resource damage profiles for shallow and deep water tables (Figure V-47) are probably a function of discounting. In shallow water tables, leachate breaks through the unsaturated zone more quickly, resulting in earlier formation of the plume. Consequently, resource damages are slightly higher for the shallow setting.

Figure V-44

CUMULATIVE FREQUENCY OF RESOURCE DAMAGE

BASELINE: USE VALUE AND OPTION VALUE

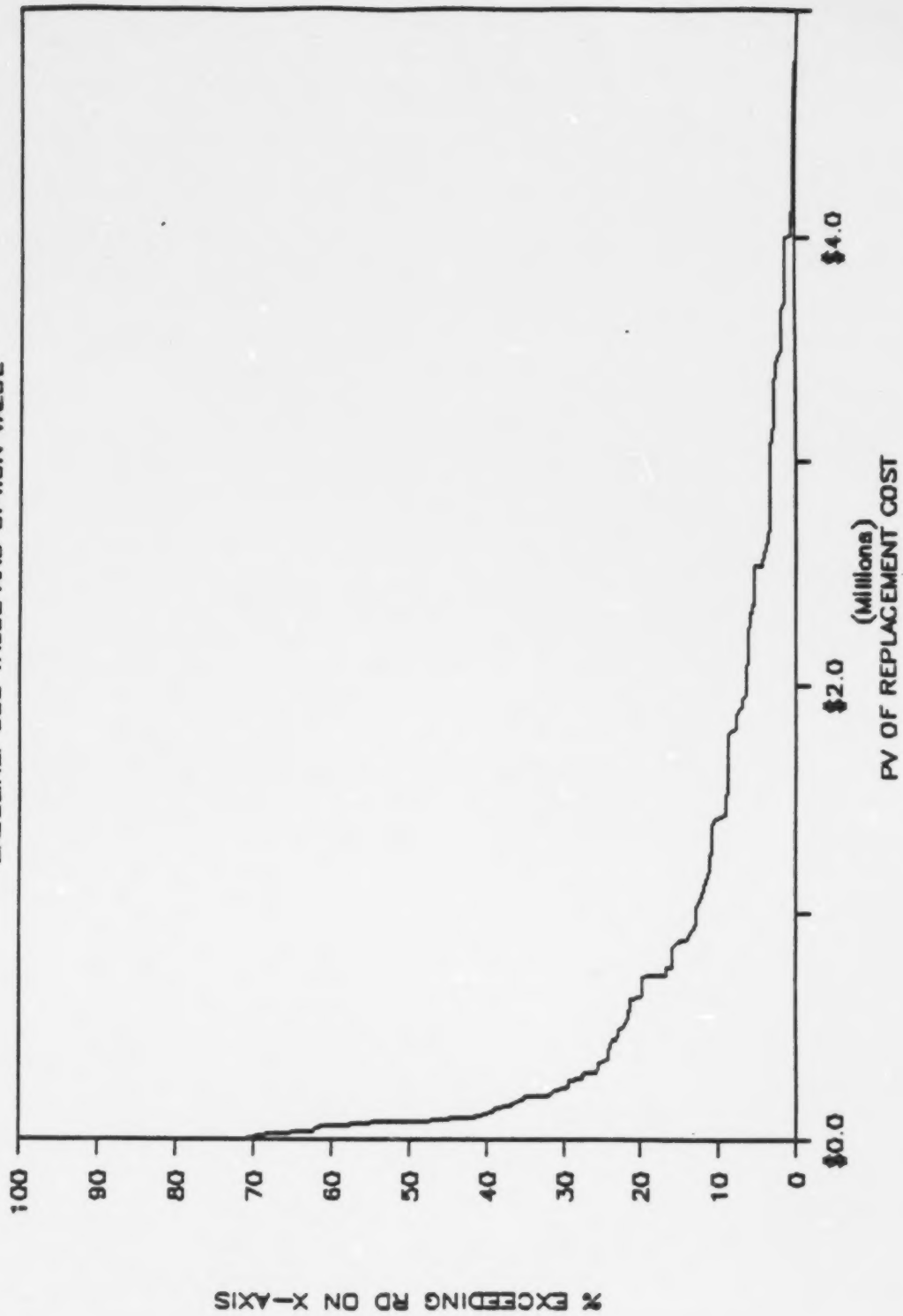


Figure V-45

CUMULATIVE FREQUENCY OF RESOURCE DAMAGE

BASELINE: USE VALUE ONLY

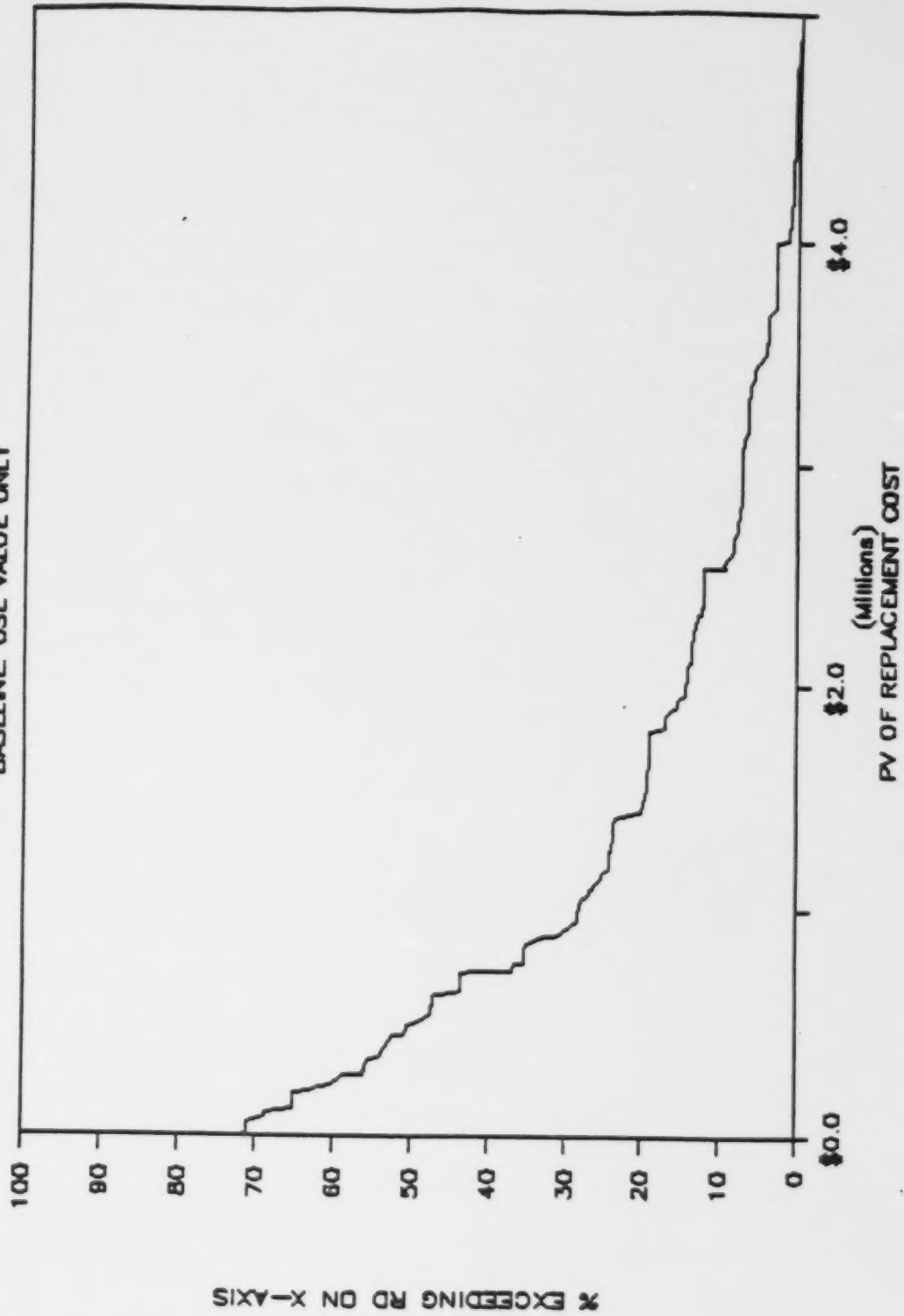


Figure V-46

DISTRIBUTION OF RD - BASELINE

BY SIZE (NORMALIZED)

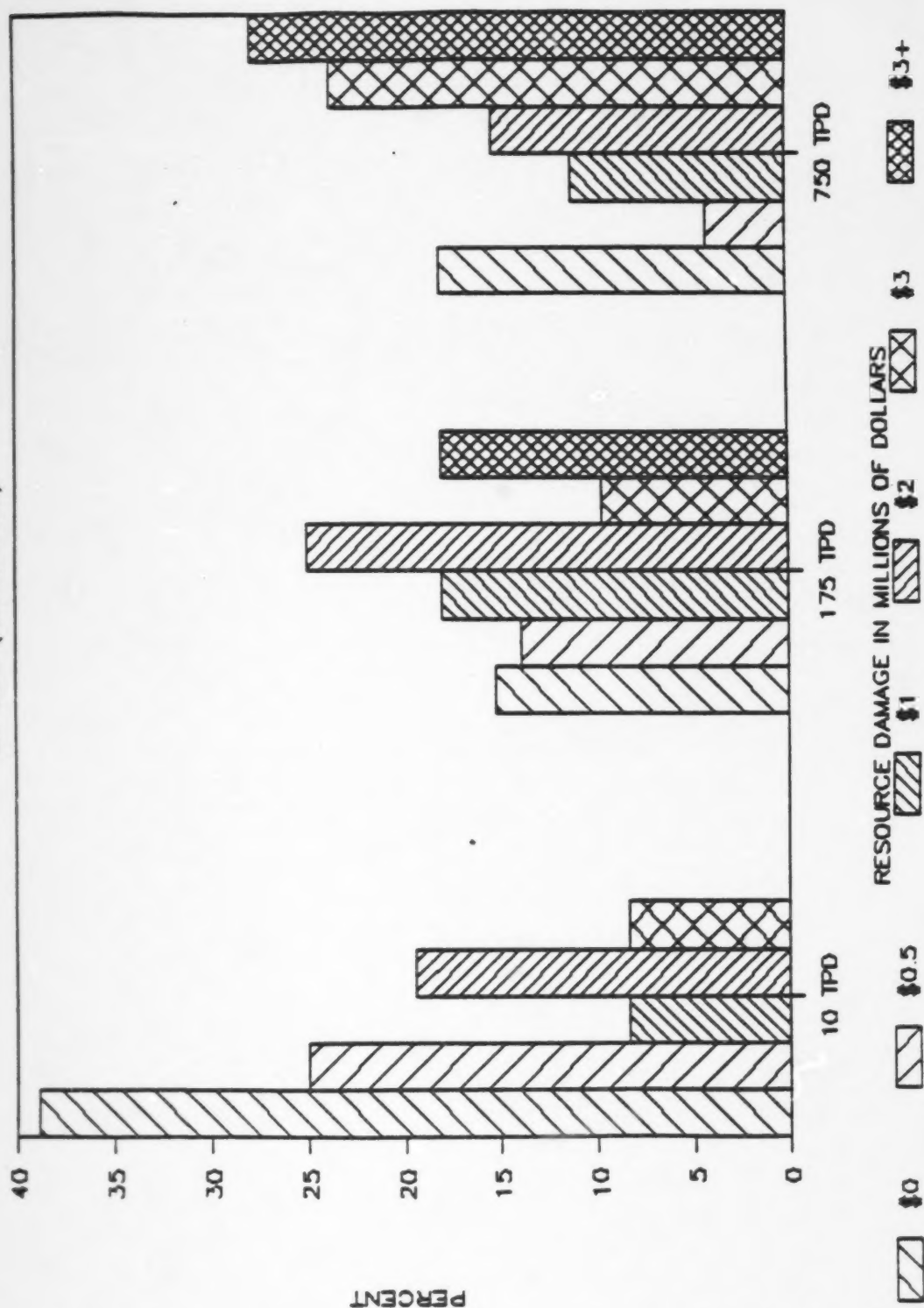
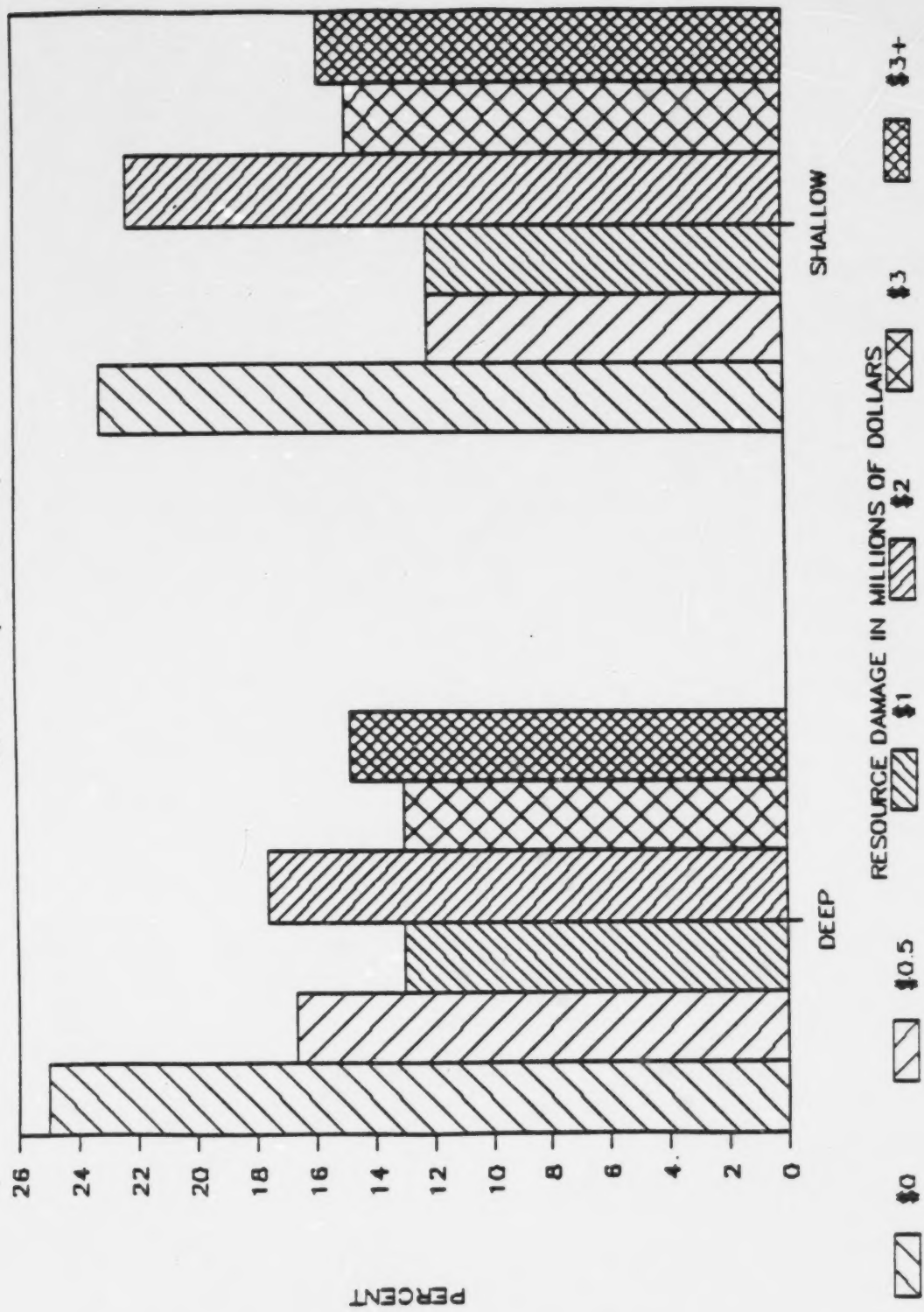


Figure V-47
DISTRIBUTION OF RD - BASELINE
 BY DEPTH (NORMALIZED)



- Net Infiltration. Net infiltration has a strong effect on resource damage. Infiltration affects both plume size and the timing of plume development. In wetter climates plumes tend to be larger and to occur sooner because greater pollutant mass is released earlier in the modeling period.

Figure V-48 shows the evidence of this effect. In the driest setting, 0.25-inch, most of the scenarios have no resource damage, and the number steadily decreases in the higher intervals. This pattern reverses in the 20-inch setting where a growing proportion of scenarios falls into the higher resource damage intervals. When we weight the four profiles by the proportion of landfills located in each infiltration region, however, the 0.25-inch and 10-inch settings have the most effect, mitigating the impact of the 20-inch scenarios.

- Flow Fields. Aquifer characteristics also affect resource damage. In the lowest velocity aquifers, plumes grow relatively slowly, but pollutant concentrations remain relatively high. In the highest velocity aquifers, plumes grow rapidly but also dissipate rapidly. In the moderate velocity flow fields, plumes grow rapidly and remain above threshold concentrations for a long period. Consequently, lower resource damages occur at either extreme, and higher resource damages occur in the middle velocities, as shown by Figure V-49. Flow field A and flow fields D and E, the slowest and the two fastest aquifers, respectively, have lower resource damage profiles. On the other hand, the moderate velocity flow fields B and C have the highest resource damage profiles.

The double-layer flow fields follow a similar pattern. Flow fields G and H behave like B and C except that the top aquifer delays plume development and dilutes contaminant concentrations (plume size is estimated for the lower layer). Figure V-49 shows a slight shift to low resource damage resulting from these effects. Flow fields F and K (confined aquifers) behave like hybrids between A and C, and A and B. The aquitards delay and disperse contamination, producing lower resource damage profiles. Flow fields A, B, C, and G have the highest proportion of landfills. Consequently, they have the greatest effect on weighted, overall resource damage.

- Summary. Estimates of resource damage are heavily dependent on the current status of ground-water use, plume size, and the timing of contamination. Because ground water in the vicinity of more than half the

Figure V-48

DISTRIBUTION OF RD - BASELINE

BY INFILTRATION RATE (NORMALIZED)

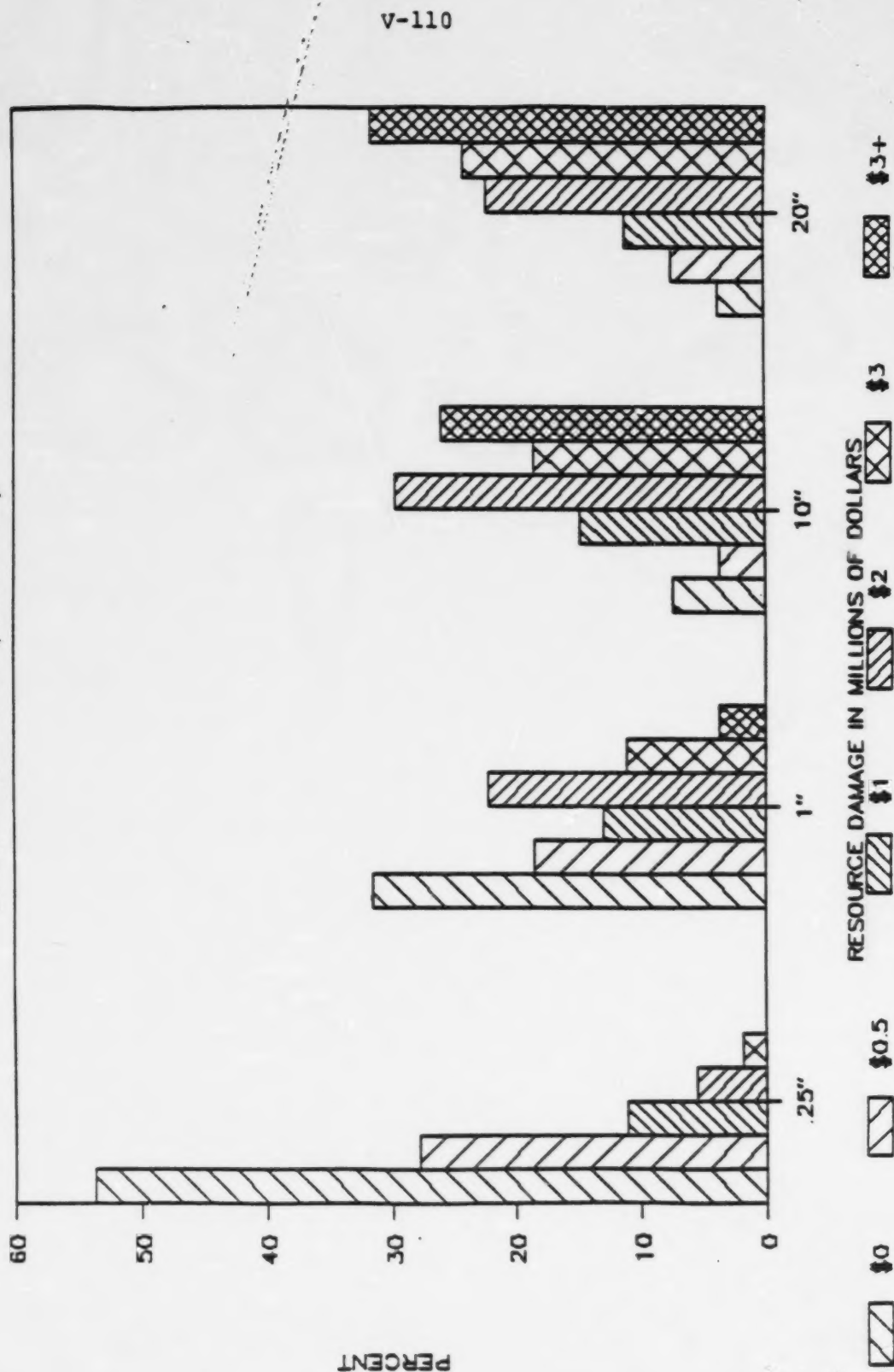
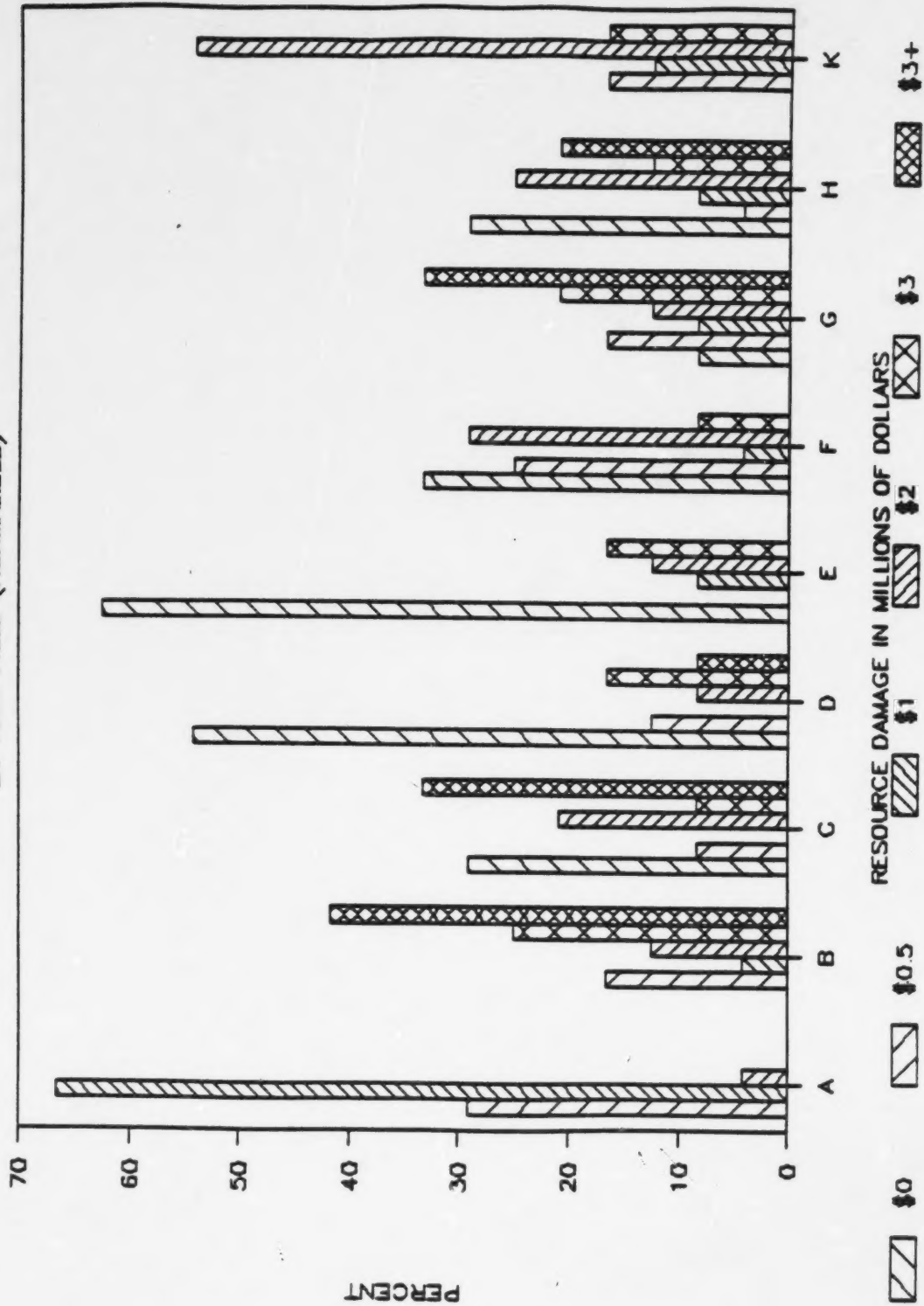


Figure V-49

DISTRIBUTION OF RD - BASELINE

BY FLOW FIELD (NORMALIZED)



landfills is not currently used, most contamination causes resource damage that has relatively low present value. In some cases, however, resource damage can be extensive, valued at as much as \$5 million. Environmental factors have an impact on resource damage by affecting plume size and its timing.

Resource Damage Reduction--Proposal

In this section we discuss the effectiveness of the Proposal in reducing resource damage, first for the 10-meter point of compliance and then for the 150-meter compliance point.

Proposal--10-Meter Point of Compliance (POC)

This modeled version of the Proposal assumes that landfills must comply with a 10^{-5} design goal at the unit boundary. As discussed previously, we estimate that vegetative covers alone are sufficient to meet the performance standard at 61 percent of all landfills; 11 percent require synthetic covers; and 28 percent need synthetic liners, LCSs, and synthetic covers. About 40 percent of those with synthetic liners and covers (11 percent of all landfills) trigger corrective action.

Figure V-50 shows the distribution of replacement costs for both the baseline and the Proposal (10-meter POC). The distributions show a shift to lower replacement costs under the Proposal. Under the Proposal, no landfills have replacement costs exceeding \$3 million (present value), compared to over 3 percent in the baseline. The fraction of landfills with replacement costs of \$1 million to \$3 million decreases from 9.5 percent in the baseline to 6.5 percent under the Proposal. The percentage of landfills with no resource damages is 28.6 for both the baseline and the Proposal.

The median replacement cost under the federal version of the Proposal is about \$63,750, compared to \$79,000 in the baseline. The total resource damage across all landfills is \$1.27 billion, a reduction of \$1.31 billion from the baseline.

Figure V-51 shows the reduction in resource damage achieved under the Proposal for all combinations of landfill size, environmental setting, and flow field, and for two measures of resource damage: use value and option value. The points plotted in this figure do not reflect the frequency of occurrence of each combination. The figure shows the effect of applying different designs to landfills. Landfills that meet the performance

Figure V-50

**DISTRIBUTION OF RESOURCE DAMAGE
PROPOSED OPTION (10-METER POC) AND BASELINE**

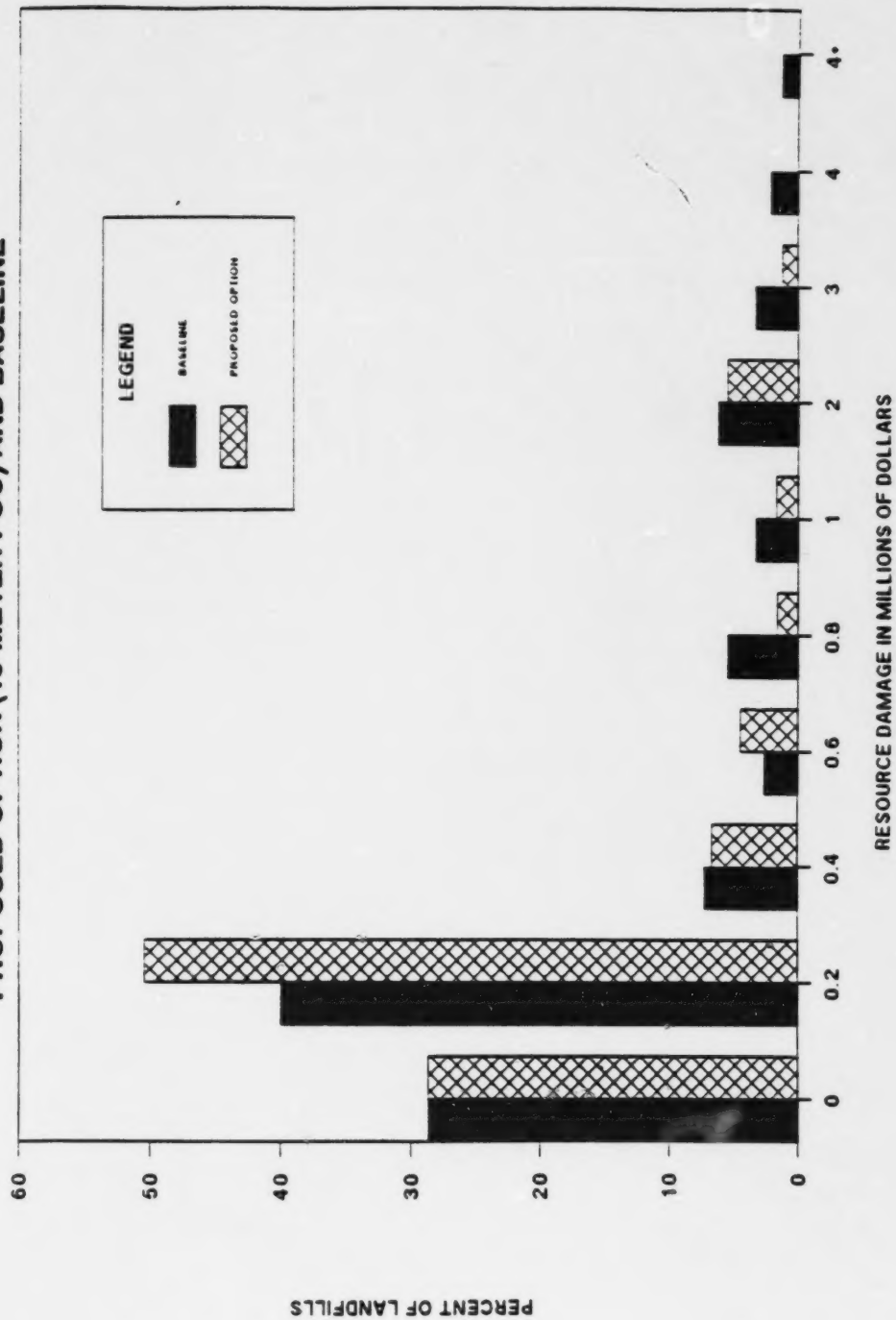
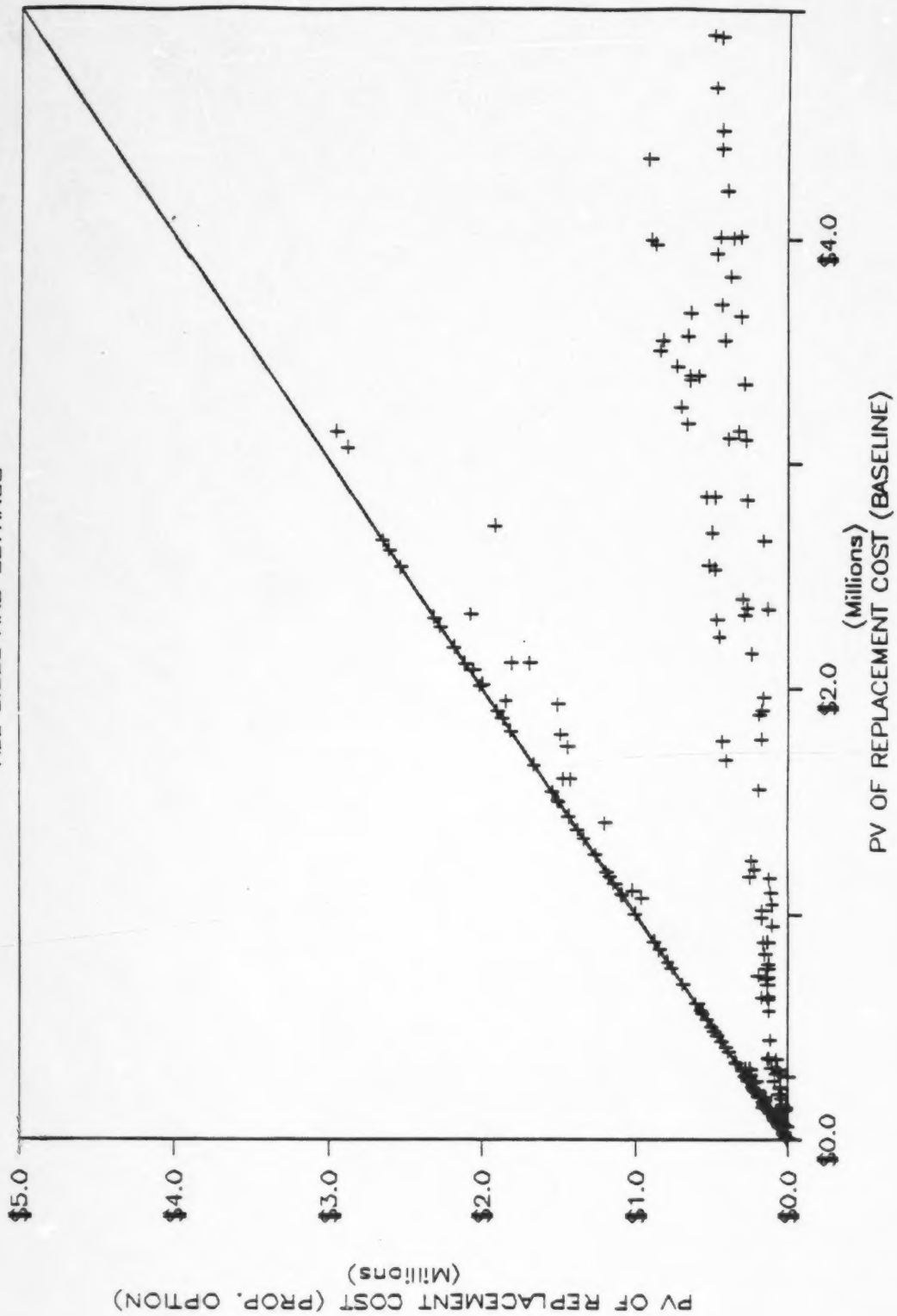


Figure V-51

BASELINE VS. PROP. OPT. (10-METER POC), R.D.

ALL SIZES AND SETTINGS



standard in the baseline (i.e., with vegetative covers and no liners) have no reduction in resource damage (i.e., points on the 45-degree line). The greatest reductions occur at landfills constructed with both synthetic liners and synthetic covers. We assume that these containment systems typically remain intact during the 20-year active life and the first 30 years of post-closure care. All other factors being equal, this 50-year delay in leachate release reduces the present value of the replacement costs by 77 percent. Moreover, the delay in release can affect the size of the plume by reducing the amount of pollutant mass released during the modeling period. Corrective action also reduces resource damage by limiting the size and duration of the plume.

For scenarios with baseline replacement costs under \$0.4 million, the reductions are relatively small. Most of the positive but low baseline replacement costs are associated with units that do not currently use ground water, where resource damage is measured in terms of option value; baseline costs above \$0.4 million are associated with units that currently use ground water, where we measure resource damage in terms of use value. Generally, use values are reduced largely because of the delay in leachate release afforded by the containment systems. Our calculations of baseline option value, on the other hand, already account for the water supply not being replaced until some time in the future. Option value is therefore less sensitive to delays in plume development, and the effectiveness of the containment systems appears lower.

Proposal--150-Meter Point of Compliance

Figure V-52 shows the distribution of replacement costs for both the baseline and the Proposal employing the 150-meter compliance point. There is a shift to lower resource damage under the Proposal, although the decline is somewhat smaller when the design goal is applied at the 150-meter distance. Using this POC, no landfills have resource damage greater than \$3 million, 7 percent have replacement costs between \$1 million and \$3 million (9.5 percent in the baseline), and 64.3 percent have positive resource damage less than \$1 million (58.7 percent in the baseline).

The median replacement cost under this version of the Proposal is about \$76,000, compared to \$79,000 in the baseline. The total resource damage across all landfills is \$1.6 billion, which is \$980 million less than the baseline.

Figure V-53 shows the reduction in resource damage achieved as a result of the Proposal (150-meter POC) for all combinations

Figure V-52

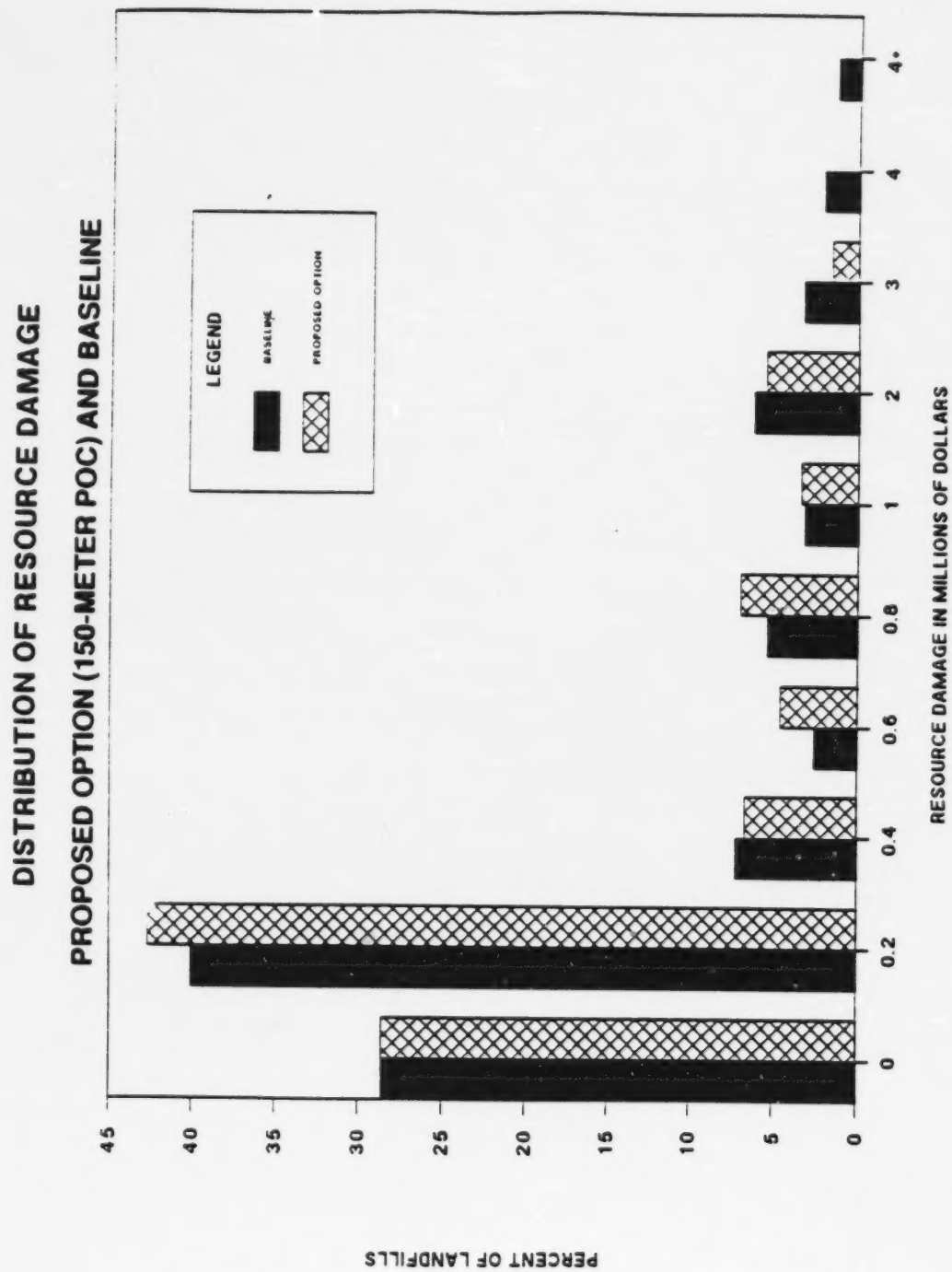
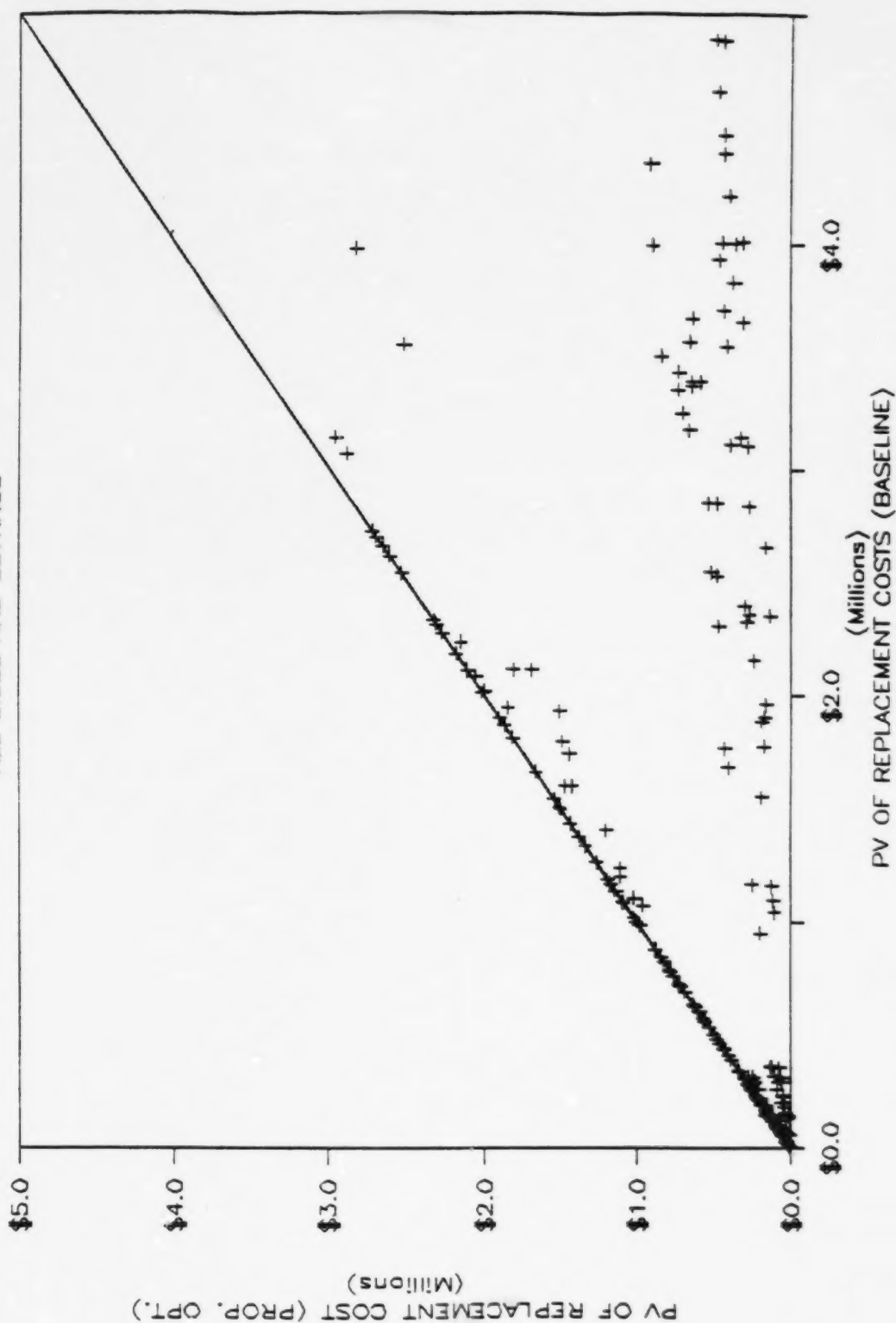


Figure V-55

BASELINE VS. PROP. OPT. (150-METER POC), R.D.

ALL SIZES AND SETTINGS



of landfill size, environmental setting, and flow field. As with other figures of this type, the points do not reflect the frequency of occurrence of each combination. Again, the amount of reduction varies depending on the liner and cover design; the greatest reductions are for landfills with synthetic liners and covers, which delay the onset of leachate release.

Figures V-52 and V-53 show that moving the point of compliance from the 10-meter unit boundary to the 150-meter alternative boundary diminishes the Proposal's effectiveness in reducing resource damage. By moving the compliance point further away from the unit so that constituent levels are generally lower, fewer landfills need the more stringent designs to meet the design goal. However, these MSWLFs will tend to produce larger plumes that exceed RD thresholds than under the closer POC. Using the 150-meter POC, 79 percent of the landfills meet the design goal in the baseline, compared to 61 percent when the compliance point is at the unit boundary. Only 21 percent of the landfills need more stringent containment under the 150-meter POC. Also, fewer landfills trigger corrective action when the compliance point is moved to the 150-meter boundary.

Resource Damage Reduction-- Alternative 1

Alternative 1 requires all new landfills to have a synthetic/composite liner, two leachate collection systems, a composite cover, and extended post-closure care. Corrective action is triggered if risks exceed 10^{-5} at the unit boundary. Figure V-54 shows the distribution of resource damage both for the baseline and with Alternative 1 requirements in place. Under Alternative 1, no landfills have replacement costs exceeding \$1 million, whereas about 13 percent have replacement costs ranging from \$1 million to over \$4 million in the baseline. The fraction of landfills with replacement costs between \$0.2 million and \$1 million decreases from one-fifth to less than one-tenth under Alternative 1. Over half of the landfills have zero resource damage with Alternative 1 requirements in place, compared to 29 percent in the baseline. The median replacement cost therefore is zero. The total resource damage across all landfills is \$410 million, a reduction of \$2.17 billion from the baseline.

Figure V-55 shows the reduction in replacement costs achieved as a result of Alternative 1 for all combinations of landfill size, environmental setting, and flow field, and for two measures of resource damage: use value and option value. The figure shows that, except for scenarios with low replacement costs in the baseline, most replacement costs are reduced by 80 percent or more as a result of Alternative 1 requirements.

Figure V-54

DISTRIBUTION OF RESOURCE DAMAGE

ALTERNATIVE 1 AND BASELINE

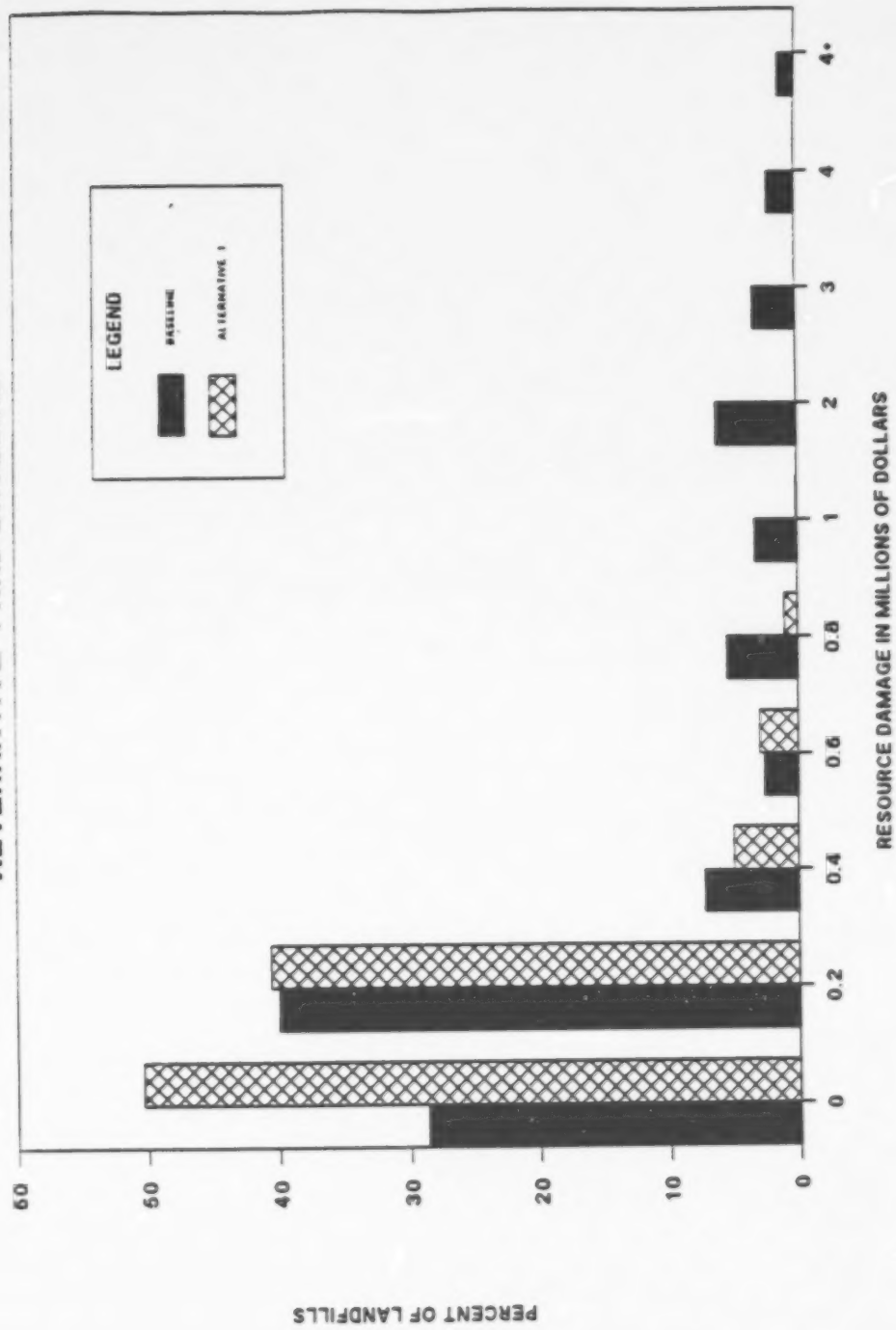
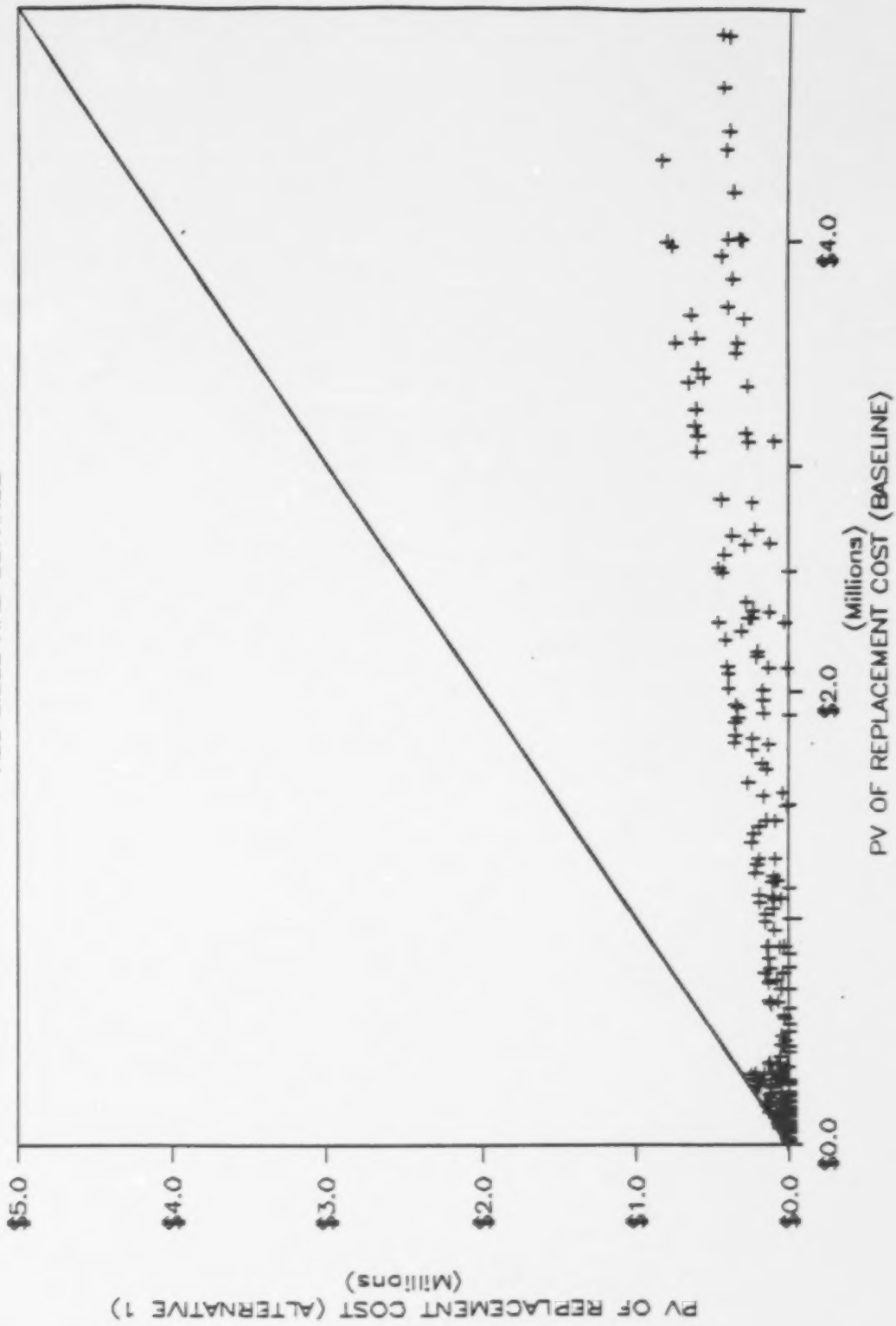


Figure V-55

BASELINE VS. ALTERNATIVE 1, R.D.

ALL SIZES AND SETTINGS



(As discussed in the preceding section on resource damage under the Proposal, the effectiveness is lower for the combinations with low resource damage in the baseline, which are generally associated with option value.)

The synthetic/composite liner, double leachate collection systems, and composite cover reduce resource damage by delaying the release of leachate and limiting the size of the plume. Corrective action, which is triggered at about 9 percent of the new landfills under Alternative 1, also contributes to the reduction in resource damage, although only by a small amount. We estimate that corrective action accounts for \$110 million of the \$2.17 billion reduction under Alternative 1.

Resource Damage Reduction--Alternative 2

Under Alternative 2, landfills must meet performance standards related to time of travel to the uppermost aquifer and infiltration of water through the cover. If the landfill generates more than a foot of leachate during its active life, it must have a leachate collection system. As discussed earlier, we made some simplifying assumptions to assign landfills to one of four designs: unlined/vegetative cover, clay-lined/vegetative cover, unlined/synthetic cover, and synthetic-lined/synthetic cover. We modeled extended post-closure care, with corrective action triggered if 300-year average most exposed individual risk exceeds 10^{-5} at the unit boundary.

Figure V-56 shows that Alternative 2 reduces resource damage quite effectively. Virtually none of the landfills have resource damages exceeding \$1 million, compared to about 17 percent in the baseline. The percent of landfills with resource damage between \$0.2 million and \$1 million decreases from 15.1 in the baseline to 12.8 under Alternative 2. About 35 percent of the landfills have no resource damage under Alternative 2, compared to about 29 percent in the baseline. The median replacement cost decreases from a baseline of \$79,000 to \$52,300, and the total resource damage across all landfills decreases from \$2.58 billion to \$570 million under Alternative 2.

Figure V-57 shows the resource damage reduction achieved under Alternative 2 for each size/setting/flow field combination. For landfills that meet the performance requirements in the baseline (i.e., with vegetative covers and no liners), there is no reduction in replacement costs; however, these landfills virtually always have very low resource damage in the baseline. For landfills that need some type of containment system to meet the time-of-travel or infiltration performance standard, use value is generally reduced by 75 percent or more. As with the other alternatives, the reductions in option value are smaller.

Figure V-56

DISTRIBUTION OF RESOURCE DAMAGE ALTERNATIVE 2 AND BASELINE

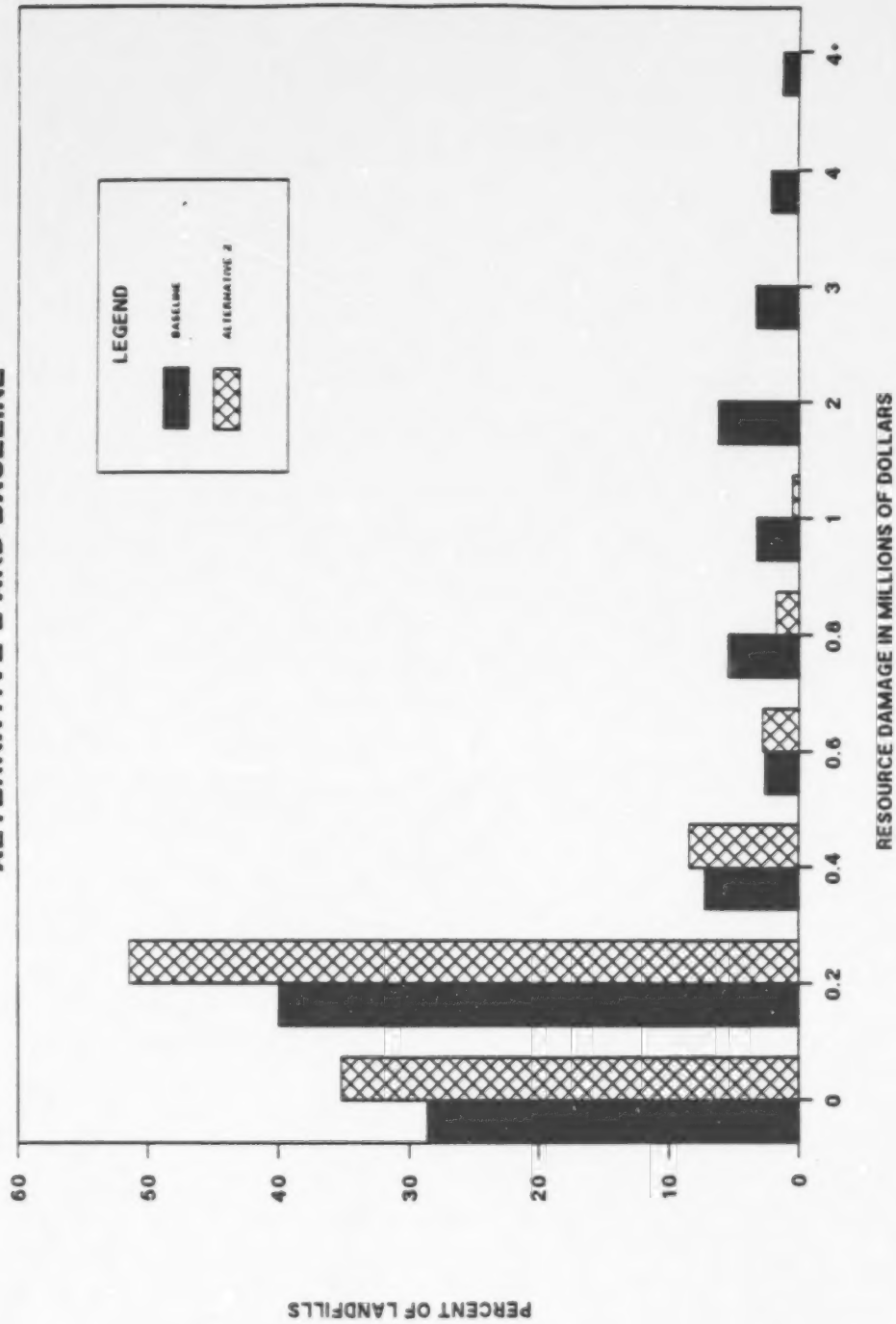
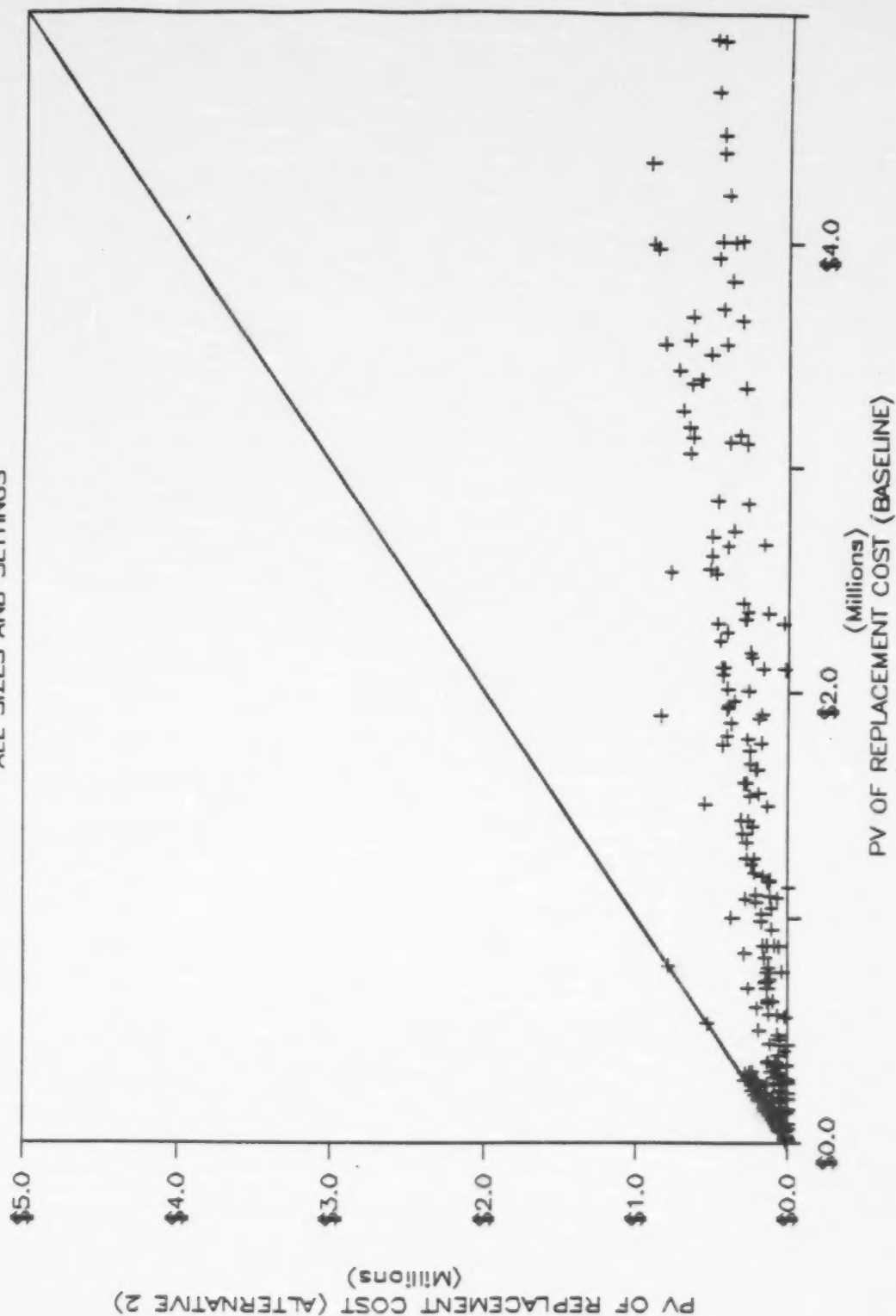


Figure V-57

BASELINE VS. ALTERNATIVE 2, R.D.

ALL SIZES AND SETTINGS



Resource Damage Reduction--Alternative 3

Alternative 3 requires landfill owner/operators to perform corrective action when individual risk exceeds 10^{-5} at the unit boundary. As Figure V-58 shows, corrective action eliminates the occurrence of replacement costs higher than \$4 million. About 6.4 percent of the landfills have replacement costs between \$1 million and \$4 million under Alternative 3, compared to 11.5 percent in the baseline. The number of landfills with no resource damage remains virtually unchanged from the baseline, at about 29 percent. The median replacement cost under Alternative 3 is about \$56,000, which is \$23,000 lower than the baseline. The total resource damage across all landfills drops from \$2.58 billion to \$1.57 billion as a result of corrective action.

Figure V-59 shows the reduction in resource damage achieved under Alternative 3 for all combinations of landfill size, environmental setting, and flow field. The points on the equal-risk line are associated with landfills that do not trigger corrective action. For landfills that trigger corrective action, the reductions range from about 10 to 80 percent.

Figures V-58 and V-59 show that corrective action alone is less effective at reducing resource damage than the use of more stringent containment system designs. Although corrective action can limit the size and duration of the plume, it does not delay the release of leachate from the landfill and as a result there is less discounting of costs.

Resource Damage Reduction--Summary

All of the regulatory options reduce resource damage from baseline levels. For each option, the largest reductions occur at facilities that currently have downgradient wells within one mile as reported in the MSWLF survey. Table V-35 shows the reduction in resource damage achieved for all of the regulatory options. Alternative 1, which imposes the most stringent containment system requirements on all landfills, reduces resource damage most effectively. Alternative 2, which requires landfills to comply with performance standards relating to time of travel and infiltration, is almost as effective as Alternative 1.

The ranking continues with the Proposal (10-meter POC), Alternative 3, and then the Proposal (150-meter POC). All three of these options target only those landfills with high (greater than 10^{-5}) human health risks, and therefore affect a relatively

Figure V-58

DISTRIBUTION OF RESOURCE DAMAGE ALTERNATIVE 3 AND BASELINE

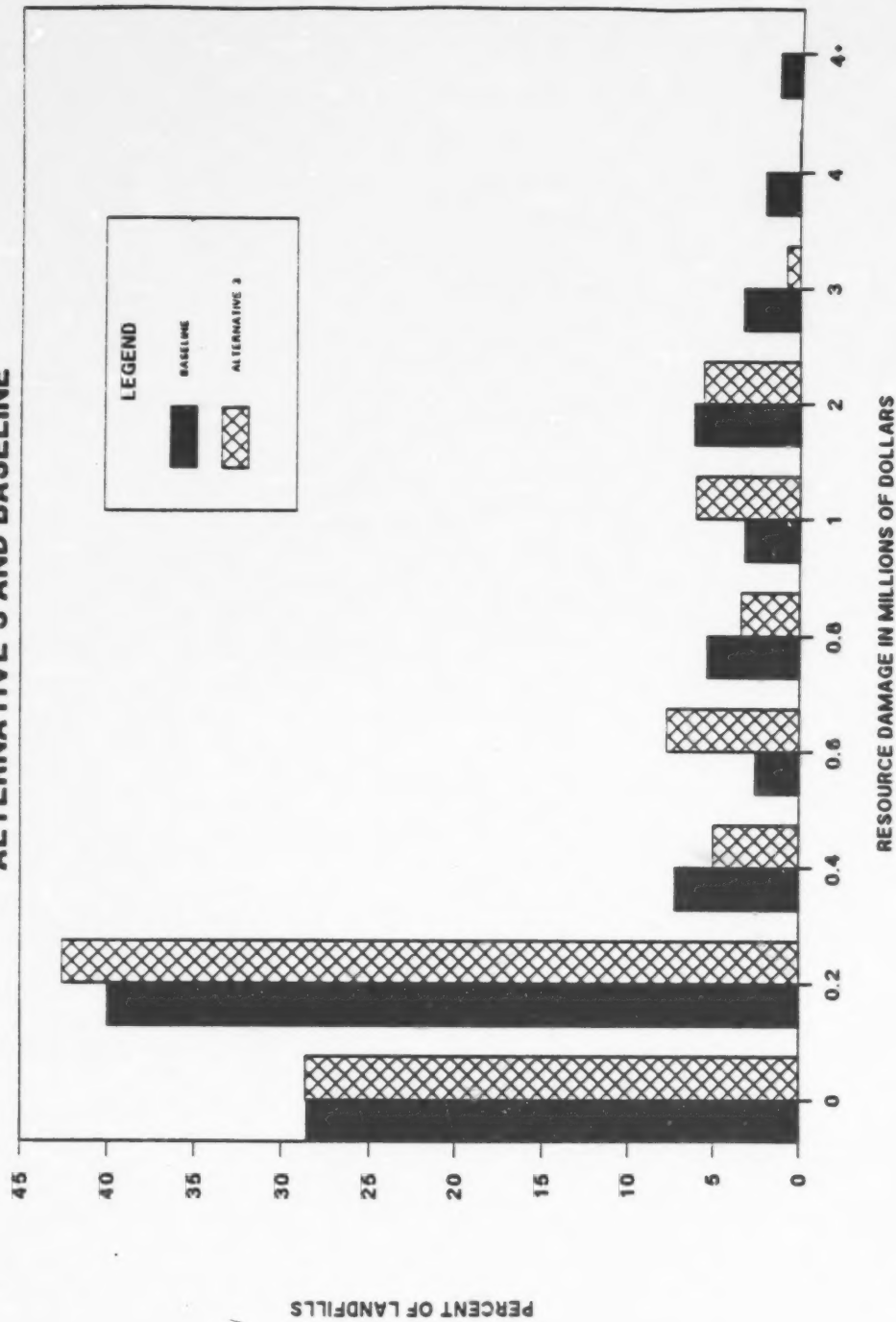


Figure V-59

BASELINE VS. ALTERNATIVE 3, R.D.

ALL SIZES AND SETTINGS

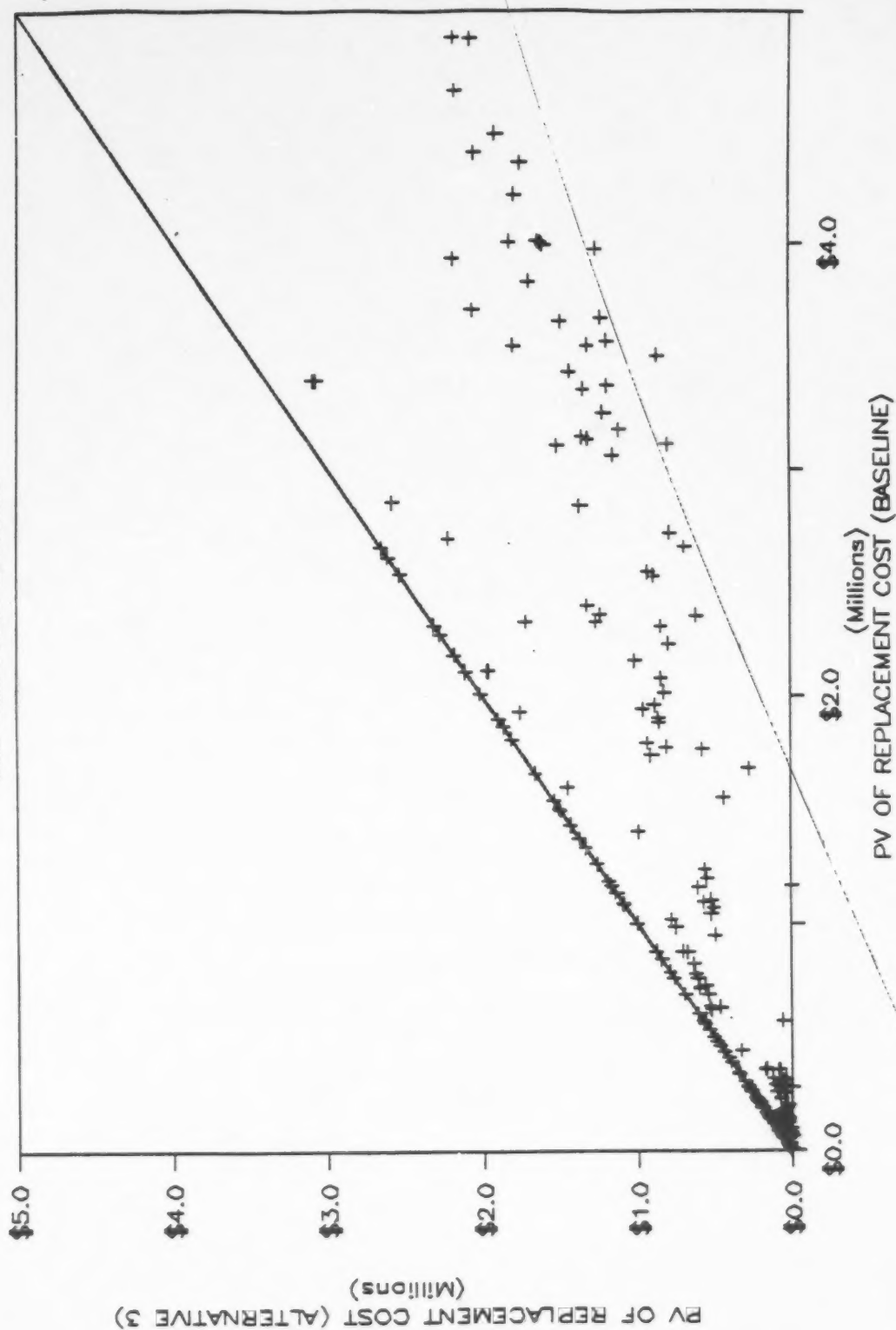


Table V-35

TOTAL RESOURCE DAMAGES FOR 6,034 NEW FACILITIES

(present value in billions of dollars)

<u>Regulatory Scenario</u>	<u>Resource Damage</u>	<u>Damage Reduction</u>
Baseline	\$2.58	-
Proposal (10-Meter POC)	1.27	\$1.31
Proposal (150-Meter POC)	1.60	0.98
Alternative 1	0.41	2.17
Alternative 2	0.57	2.01
Alternative 3	1.57	1.01

small fraction of the facilities. The Proposal with the more distant POC is the least effective of these three options because its compliance point is at 150 meters, and the number of landfills affected is smaller than under any other alternative.

VI. COST-EFFECTIVENESS

Cost-effectiveness is a convenient summary measure of the relative benefits, given the compliance costs of the Proposal and the regulatory alternatives. In this analysis, we have reported the costs of each option as the incremental cost compared to the analytical baseline of modeled, current costs. The measures of effectiveness are reductions in human health risk and in resource damage, calculated as the cost to replace contaminated water supplies for current or potential users. In Chapter V, we compared the costs of the different options and showed the relative effectiveness of each in reducing risk and resource damage. To conclude the analysis, we have summarized the effectiveness of each option per dollar spent.

The cost-effectiveness estimates have several limitations because of the assumptions made in the RIA. First, the two categories of benefits deal with ground-water-related effects: risk from drinking contaminated ground water and the avoided cost of new water supplies (resource damage). The cost estimates, however, are not limited to measures that protect ground water; they include requirements that would reduce risks in other areas including surface water and subsurface gas. As a result, in the cost-effectiveness calculations, we are attributing to some options a higher cost than is incurred primarily for ground-water protection. At the same time, however, the ground-water protection costs account for a large percentage of incremental costs, so the cost-effectiveness ratios are reasonable estimates.

The second limitation is that these ratios only address cost-effectiveness at new MSWLFs. In order to present consistent measures of cost and effectiveness, we were obligated to modify the cost results somewhat. The cost model calculates costs for new and existing landfills; however, the risk model simulates risk and resource damage for new units that begin operation at the start of the simulation period and close after 20 years. We model releases for 100 years after the unit first accepts waste. The model then tracks any releases that occur for up to 200 years, so the overall model simulation period is 300 years for each unit. For comparative purposes, then, we only used costs for new MSWLFs with no replacement landfills. The costs assume that the units will open in the first year of the simulation period, complete with all necessary design requirements. The units operate for 20 years and are maintained for the appropriate post-closure care period. Corrective action costs for new units are added as appropriate. Even though we analyzed corrective action costs at existing units, these are not included in the cost-effectiveness results because we have no measures of effectiveness at existing units.

The third limitation on the cost-effectiveness results is actually a caveat against combining the effectiveness measures: it is not appropriate to combine risk and resource damage estimates to calculate "total" benefits. The risk estimates assume that people continue to drink water contaminated with the constituents of concern. The risk reduction is a function of lower levels of contaminants in the drinking water. Resource damage, on the other hand, assumes that as soon as contamination is detected, people stop drinking the water and switch to an alternative drinking water supply. It is not appropriate, therefore, to attribute any risk reduction benefits if resource damage estimates are used. These two measures are best seen as two distinct approaches for measuring benefits. Risk emphasizes human health effects to current users without regard for the time at which they are exposed. Resource damage measures economic benefits (avoided costs) for current and potential users and incorporates timing by discounting future benefits: if contamination is merely delayed, not prevented, RD would show an improvement while risks would not. RD is also important because it measures effectiveness at all units, not just the 46 percent with wells where risk is measured.

The final limitation is a result of the assumptions used to simulate compliance with the design goal. The Proposal provides a protective range of 10^{-4} to 10^{-7} for the design goal, but we modeled the Proposal assuming the design goal was 10^{-5} for all landfills. To the extent that states select other goals in the range, the cost-effectiveness of the Proposal would change.

COSTS OF RISK REDUCTION

In order to compare risk reduction with incremental costs, we must match both measures to capture the same effects over the same period of time. The Risk Model estimated the number of cases that would occur for each landfill over each year of the simulation. Aggregating to the population, the model calculated the total number of cases per year for the baseline and each regulatory option. To compare the number of cases with the costs, we summed the number of cases over the 300-year period. These are shown in Table VI-1. Based on the analysis of Risk Model runs, Alternative 1 is the most effective at reducing cases, and the Proposal using the 150-meter POC is the least effective, but the range is quite small. We discussed the reasons for the differing effectiveness in Chapter V.

Table VI-1
CASES OVER 300 YEARS

	<u>Cases Per Year</u>	<u>Total Number of Cases</u>	<u>Cases Avoided</u>
Baseline	0.0770	23.1	--
Proposal (10-Meter POC)	0.0210	6.3	16.8
Proposal (150-Meter POC)	0.0227	6.8	16.3
Alternative 1	0.0086	2.6	20.5
Alternative 2	0.0105	3.2	20.0
Alternative 3	0.0216	6.5	16.6

For costs, we summed all the costs that would be incurred for each new landfill (including corrective action) and calculated the present value of costs for all landfills and also for the subset of landfills that have ground-water wells within one mile downgradient as reported in the MSWLF survey. Both costs are presented to illustrate the total cost-effectiveness of the options and then the incremental cost effectiveness of reducing risks at landfills that have wells. We expect that as more wells are drilled near landfills (or landfills are sited near existing wells), more units will have risk, so total risks and associated costs will be more similar to these estimates. As with other costs, we measured only the difference between costs with the regulation and the baseline for both scenarios.

Table VI-2 presents the incremental number of cases avoided (cases under the baseline minus cases under each option) and the incremental present value cost for each of the regulatory options for all landfills and the subset with wells. The most expensive option is Alternative 1, with Alternative 3 the least expensive.

The total cost per case avoided ranges from \$365 million for Alternative 3 to \$2,661 million for Alternative 1. The Proposal is between these alternatives in cost per case avoided, at \$708 million using the 10-meter POC and \$548 million using the 150-meter POC. The incremental costs vary much more than the cases avoided; some of the alternatives, therefore, impose much greater costs for only limited additional benefit. Between Alternative 2 and Alternative 1, for example, landfill owners would incur an additional \$32,809 million to avoid 0.5 additional cases over 300 years.

The largest impact on risk per dollar spent is under Alternative 3, which has the fourth largest risk reduction and the lowest incremental cost. With the exception of the Proposal

Table VI-2

COST PER CASE AVOIDED

New Units Only; 300-Year Period

		Incremental Cost (present value in millions)		Cost per Case Avoided (dollars in millions)	
		All Landfills	Landfills With Wells ¹	All Landfills	Landfills With Wells ¹
Proposal (10-Meter POC)	16.8	\$11,899	\$5,558	\$ 708	\$ 331
Proposal (150-Meter POC)	16.3	8,939	4,296	548	264
Alternative 1	20.5	54,548	23,641	2,661	1,153
Alternative 2	20.0	21,739	9,759	1,087	488
Alternative 3	16.6	6,065	2,830	365	170

¹These costs are computed only for the fraction of MSWLFs that reported drinking water wells within one mile of the units.

(150-meter POC), all the options provide additional risk reduction for each additional dollar spent. The Proposal with the 150-meter POC is dominated by Alternative 3 (i.e., Alternative 3 costs less and provides slightly more risk reduction).

The incremental cost and the cost per case avoided for the landfills with wells follow the same pattern as the total cost results, but at a lower absolute level. The cost per case avoided ranges from a low of \$170 million for Alternative 3 to a high of \$1,153 million for Alternative 1. The Proposal cost is \$331 million per case avoided using the 10-meter POC and \$264 million per case using the 150-meter POC.

COSTS FOR RESOURCE DAMAGE REDUCTION

Again, we adjusted the model results to allow us to match consistent results over consistent time periods. The Risk Model calculates resource damage for individual units in present value terms. The sums of the present value of resource damage as estimated by the model are shown in Table VI-3. The baseline resource damage, which represents the maximum amount of damage incurred, is \$2,580 million. The reduction in resource damage is calculated simply as the difference between resource damage with no controls in place (the baseline) and when regulatory controls are imposed.

VI-5

Table VI-3		
PRESENT VALUE OF RESOURCE DAMAGE		
New Units Only		
(dollars in millions)		
	<u>Resource Damage</u>	<u>Avoided Resource Damage</u>
Baseline	\$2,580	--
Proposal (10-Meter POC)	1,270	\$1,310
Proposal (150-Meter POC)	1,600	980
Alternative 1	410	2,170
Alternative 2	570	2,010
Alternative 3	1,570	1,010

Table VI-4 presents the estimates for avoided resource damage under each of the options and the corresponding compliance costs. Alternative 1 provides the most benefit in terms of avoided resource damage, and Alternative 2 avoids the second most resource damage. As with risks, the Proposal (150-meter POC) provides fewer benefits at a higher cost than Alternative 3. Explanations of the relative effectiveness of the options are given in Chapter V.

Table VI-4			
NET BENEFIT OF RESOURCE DAMAGE IMPROVEMENTS			
(present values in millions of dollars)			
	<u>Avoided Resource Damage</u>	<u>Incremental Cost</u>	<u>Benefit/Cost</u>
Proposal (10-Meter POC)	\$1,310	\$11,899	0.110
Proposal (150-Meter POC)	980	8,939	0.110
Alternative 1	2,170	54,548	0.040
Alternative 2	2,010	21,739	0.092
Alternative 3	1,010	6,065	0.167

To compare benefits with costs, we calculated an incremental benefit/cost ratio. When this ratio is less than 1, costs exceed benefits. The ratio is less than 1 for all the options. However, Alternative 3 has the highest ratio, 0.167. The Proposal (for both POCs) is next with a ratio of 0.110. It is important to emphasize that although Alternative 3 has the highest ratio of benefits to costs, it is less effective than the Proposal (10-meter POC) or Alternative 1 in reducing RD, due to its reactive approach to addressing releases.

As we observed for the costs per case avoided, some of the additional expenditures for the more expensive options buy very little additional resource damage reduction. For example, a move from Alternative 2 to Alternative 1 would avoid \$160 million in RD, but at a present value cost of \$32,800 million, an incremental benefit/cost ratio of 0.005.

SUMMARY

The costs per case avoided from new landfills are relatively high in an absolute sense, but the most useful aspect of the analysis is the indication of the relative effects of the different options. The relative cost-effectiveness could change if states choose a design goal for the Proposal that differs from our assumed 10^{-5} goal. Given the current modeling assumptions and the regulatory options, the Proposal is dominated by Alternative 3 in both cost per case avoided and net benefits of resource damage improvements. Each option is ranked in Table VI-5. We can conclude that Alternative 3, with its emphasis on correcting releases from leaking landfills, is the best option from a pure cost-effectiveness standpoint. However, reliance on a reactive approach also brings the most uncertainty in the effectiveness and cost of corrective action. This uncertainty in the efficacy of remedial measures may not be well reflected in the model results. While the results may depend to a large extent on modeling assumptions, the analysis supports the principle of imposing preventative controls on landfills where the impacts are likely to be most severe.

Table VI-5
SUMMARY OF COST-EFFECTIVENESS

Risk				Resource Damage		
Rank	Option	Cost per Case Avoided (dollars in millions)		Rank	Option	Benefit/Cost
		All Landfills	Landfills With Wells			
1	Alternative 3	\$ 365	\$ 170	1	Alternative 3	0.167
2	Proposal (150-Meter POC)	548	264	2	Proposal (150-Meter POC)	0.110
3	Proposal (10-Meter POC)	708	331	3	Proposal (10-Meter POC)	0.110
4	Alternative 2	1,087	488	4	Alternative 2	0.092
5	Alternative 1	2,661	1,153	5	Alternative 1	0.040